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PAPERS AND PROCEEDINGS

OF

The Royal Society of Tasmania

Volume 97

Edited by William Bryden

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The Royal Society of Tasmania

Volume 97

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ERRATA

PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA, VOLUME 98.

University of Tasmania Geology Department Publication no. 142.

GROVES, D.I. AND SOLOMON, M. THE GEOLOGY OF THE MT. BISCHOFF DISTRICT.

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Royal Society of Tasmania

Annual Report for the Year 1962.

Meetings.

One of the outstanding interests in the Society during the past year was the initiation of a new series of scientific lectures provided for all members but more especially for those with a good background of scientific knowledge. These lectures received very good support from members and the Council of the Society has decided to continue the practice.

The following lectures were given in this series:—

June: "Chromosome Abnormalities in Man". Professor A. M. Clark.
July: "Permeability of the Cell Membrane". Dr. R. K. Crowdon.
September: "Seismic Research". Professor G. Newstead.

General Meetings of the Society were held as usual each month from March to November inclusive and the following lectures were given:—

March: "A Van Diemen's Land Demagogue". Mr. F. Green.
April: "The Route of Luis Vaez de Torres from the New Hebrides to Torres Strait, August-September, 1606". Mr. G. A. V. Stanley.
May: "Electro-Chemistry—the Key to Tasmania's Prosperity". Professor H. Bloom.
June: "The Origins of the English Bar". Professor N. C. H. Dunbar.
July: "The Fundamental Particles of Matter". Dr. A. G. Fenton.
August: "Myxomatosis in South Australia". Dr. I. S. Wilson.
September: "Hydatid Disease". Dr. T. C. Beard.
October: "Fossil Liverworts". Dr. J. A. Townrow.
November: "Australia's Relations with the New Malaysia". Dr. P. J. Boyce.

Papers and Proceedings.

Volume 96 of the *Papers and Proceedings* was published during the year and following our usual custom exchanges were effected with libraries and scientific institutions in all parts of the world. We have had many requests for volumes of the *Papers and Proceedings* from libraries in many countries and at present it is not possible to supply some of the early volumes. Council agreed that the difficulty might be overcome by providing photostat copies and it is possible this will be done in the next twelve months.

Library.

Four hundred and forty volumes, books and journals were added during the year. Acting on a decision made in 1961 and set out in the Annual Report for that year, a number of old and out-of-date texts were removed from the shelves.

Further progress has been made microfilming a number of the unique and valuable documents in the Society's collection and will be continued in the following years.

Northern Branch.

The Branch of the Society in Launceston had another successful year and continued their meetings and excursions for members. The Wedge Papers were set after many delays and these should be available in the near future.

Late in November the full Council met in Launceston.

Annual Meeting.

The Annual General Meeting was held on Tuesday, 6th March, 1962, and was presided over by His Excellency the Governor of Tasmania, the Lord Rowallan, President of the Society.

The Annual Report and Statement of Accounts for the year 1961 were presented to members and adopted.

The following office-bearers were elected:—

Vice-President: Professor Gordon Newstead.

Honorary Secretary and Honorary Librarian: Dr. W. Bryden.

Honorary Treasurer: Mr. G. E. A. Hale.

Honorary Auditor: Mr. A. M. Hewer.

Council Members: Mr. R. M. H. Garvie and Dr. D. Martin.

The following appointments to Committees were made by Council:—

Standing Committee: Mr. R. M. H. Garvie, Dr. D. Martin, Dr. W. Bryden, and one Northern representative.

Representatives on the Board of Trustees of the Tasmanian Museum and Art Gallery: Mr. G. F. Davies and Dr. D. Martin.

Representative on the Board of Trustees of the Botanical Gardens: Mr. R. S. McIntyre.

Representative on the Nomenclature Board: Mr. E. R. Pretyman.

Representative on the Mount Field National Park Board: Dr. J. M. Gilbert.

Representative on the Library Association of Australia: Dr. W. Bryden.

Acknowledgments.

The Society is grateful to the Government of Tasmania; the State Library, the Tasmanian Museum and Art Gallery, Hobart; the Queen Victoria Museum, Launceston; the University of Tasmania, the Office-Bearers, Lecturers, Staff, Donors and all others who have assisted the Society to carry out its work during the year.

ROWALLAN, President.

Royal Society of Tasmania

Papers and Proceedings Volume 97

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Northern Branch

Annual Report, 1962.

Following the Annual General Meeting in March, the Council of the Northern Branch was composed as follows:—

Chairman: Mrs. I. J. Mead.
Vice-Chairman: Mr. T. E. Burns.
Past Chairman: Dr. C. Craig.
Honorary Secretary and Treasurer: Mr. W. F. Ellis.
Members of Council: Mrs. B. J. Edwards, Mr. J. M. Curtis, Dr. J. C. H. Morris, Mr. J. R. Skemp, Mr. K. R. von Stieglitz.

Mrs. Mead and Mr. Ellis represented the Northern Branch on the General Council and Mrs. Mead served as a member of the Standing Committee. Mr. Justice G. H. Crawford acted as the Branch's nominee on the Cradle Mountain-Lake St. Clair National Park Board.

Membership.

The Branch membership on 31st December, 1962, was 231 persons. During the year the following adjustments occurred:—

Elected	18
Transferred to Branch	2
Resignations	9
Deceased	1
Removed	12
Transferred from Branch	2

Activities.

Twelve General Meetings were held during the year, at which the following papers were presented:—

23*rd February*: "See how this river . . . a discussion on river regime and river control", by Mr. T. E. Emmett.

23*rd March* (Valedictory Address): "Some newly discovered watercolours of Launceston by Frederick Strange and some points on Tasmanian engravers", by Dr. C. Craig, C.M.G.

27*th April*: "Hydatids", by Dr. T. C. Beard.

25*th* May: "Problems in writing a life of R. C. Gunn", by Mr. T. E. Burns and Mr. J. R. Skemp.

22*nd June*: "The scientific explosion", by Professor S. W. Carey.

20*th July*: "Tasmanian telemetered seismic net", by Professor G. Newstead.

13*th August*: "Architects and Governors—the story of John Lee Archer", by Mr. R. S. Smith.

31*st August*: "The elementary particles of matter", by Dr. A. G. Fenton.

28*th September*: "They came to a country . . . ", by Mr. W. F. Ellis.

29*th October*: "Biological fixation of nitrogen", by Mr. H. V. Rees, and "Symbiotic nitrogen fixation in Tasmanian agriculture", by Mr. D. F. Paton.

16*th November*: "Launceston and the anti-transportation movement", by Mr. Malcolm McRae.

7*th December* (Members' Night):—

"A Relic of the Bligh rebellion", by Mr. J. M. Curtis.
"Journeying through Jerusalem", by Mrs. M. K. Whishaw.
"The Nuffield Foundation and its work", by Mr. John Lyne.
"Dr. Albert Schweitzer", by Mrs. B. J. Edwards.
"Macao", by Mr. K. R. von Stieglitz, O.B.E.

The average attendance at General Meetings during 1962 was 68.

Excursions.

Two day excursions were held:—

15*th April*: Macquarie River District.

25*th November*: Beaconsfield.

In addition, an extended excursion to places of historical interest in Southern Tasmania was held during the long week-end on 3rd-5th November. This was attended by 30 members and guests.

The Branch Council acknowledges, with appreciation, the facilities provided during the year at the Queen Victoria Museum by the Launceston City Council.

I. J. MEAD, Chairman.

W. F. ELLIS, Honorary Secretary.

OBSERVATIONS ON SOME TASMANIAN FISHES: PART XI

By

E. O. G. SCOTT

(With eight text figures)

ABSTRACT

New records for Tasmania are *Girella elevata* Macleay, 1881 (with comparison of Tasmanian and New South Wales examples); *Stigmatogobius poicilosoma* (Kner), 1865 (with notes on life colors). Reinstated on local list is *Spheroides hamiltoni* (Gray & Richardson), 1843 (earlier displaced in favour of *S. liosomus* Regan, 1909: both species occur here). Confirmatory records are given for *Ophisurus serpens* (Linné), 1758 (description of Tasmanian specimen; dentition figured); *Tetraodon armilla* McCulloch & Waite, 1915.

General observations (chief topic(s) in parentheses) are made on *Heterodontus portusjacksoni* (Meyer), 1793 (omission of Tasmania in Handbook localities, biometric data on 3 females); *Heterodontus galeatus* (Günther), 1870 (Tasmanian ?); *Cephaloscyllium isabella laticeps* (Duméril), 1853 (biometric data on 7 adults and a foetus, egg-case, description and figure of foetus, which carries 2 dorsal rows of enlarged denticles); *Myliobatis australis* Macleay, 1881 (sexual dimorphism, study of dentition); *Gonorhynchus greyi* (Richardson), 1841 (published figures reviewed)*, *Muraenichythys breviceps* Günther, 1876 (figure of head); *Leptonotus semistriatus* Kaup, 1856 (coloration)*; *Syngnathus philippi* Lucas, 1891 (figure of brood pouch, coloration, depth record)*; *Solegnathus fasciatus* (Günther), 1880 (eggs and their attachments)*, *Stigmatopora argus* (Richardson), 1840 (description and figure of brood pouch)*; *Phylloptexyx taeniolatus taeniolatus* (Lacépède), 1840 (eggs); *Nesogobius hinsbyi* (McCulloch & Ogilby), 1919 (localities, depth record); *Arenigobius bifrenatus* (Kner), 1865 (locality, coloration); *Spheroides richei* (Freminville), 1813 (dimensions, coloration, comparison with *S. hamiltoni*). In the species marked with an asterisk proportions and counts here noted extend the known range as given in the Handbook (Munro 1956 +) and, in the case of syngnathids, as set out in the conspectus (Scott, 1961).

Keys are provided covering the Tasmanian members of the families Heterodontidae, Scyliorhinidae, Girellidae, Gobiidae, Tetraodontidae.

INTRODUCTION

This paper follows the general plan of earlier contributions in this series. All linear dimensions are in millimetres; except where its absence might lead to confusion, the name of the unit is omitted. Standard length and total length are denoted by *Ls* and *Lt*; while *TLs*, *TLt*, used in recording proportions, signify thousandths of standard, thousandths of total, length. Locality records include, where practicable, the county name.

Basic data has been compared with that presented in the Handbook of Australian Fishes (Munro, 1956 +), and attention has been called to any divergences encountered.

Family HETERODONTIDAE

Only one Australian genus is usually recognized, *Heterodontus* Blainville, 1816, with 2 species: (1) *H. portusjacksoni* (Meyer), 1793, (2) *H. galeatus* (Günther), 1870; but Günther's species is sometimes referred, as in the Check List, to *Gyropleurodus* Gill, 1862, or to *Molochophrys* Whitley, 1931.

The claims to inclusion in the Tasmanian list of these 2 species are discussed below; and some dimensions of (1) are tabulated.

KEY TO AUSTRALIAN SPECIES OF HETERODONTIDAE

A. Posterior border of supraorbital ridge more nearly horizontal than vertical, lapsing tolerably evenly and gradually into general profile of head. Enlarged lateral teeth not carinate. Origin of anal slightly ($\leq \frac{1}{2}$ anal base) behind termination of second dorsal. With black or blackish harness-like markings on trunk .... *H. portusjacksoni*

AA. Posterior border of supraorbital ridge more nearly vertical than horizontal. Enlarged lateral teeth distinctly carinate. Origin of anal well ($\doteq$ anal base) behind termination of second dorsal. Without black or blackish harness-like markings on trunk .... *H. galeatus*

HETERODONTUS PORTUSJACKSONI (Meyer), 1793

Squalus portusjacksoni Meyer 1793, Zool. Entdeck.: 71. (Based — *fide* Whitley, 1934: 181— on the Port Jackson Shark figured in Philipps' *Voyage*: 166, pl. 42).

Squalus philippi Bloch & Schneider, 1801, Syst. Ichth.: 134, Type locality: 'New Holland' [= Port Jackson, *fide* McCulloch (1929:4)].

Heterodontus portusjacksoni (Meyer), 1793. Whitley, 1934, *Mem. Qld Mus.*, x, iv: 181.

Claim to inclusion in Tasmania list.—This species has been regularly included in all locally compiled Tasmanian faunal lists—Allport [unpublished: *fide* Johnston (1883)], Johnston (1883:139; 1891:39), Lord (1923:61), Lord & Scott (1924:5, 18): it is credited to Tasmania also in the Check List (McCulloch, 1929:4), and in the survey of Australian sharks and rays by Whitley (1940:72). It is indeed by no means uncommon in our waters, and I have examined a number of specimens from the north, east, and south of the Island. It hence seems expedient to draw attention to the fact that in

the latest synoptic account of Australian fishes, the valuable Handbook of Australian Fishes (Munro), currently in serial publication in the *Fisheries Newsletter*, the localities given comprise all States except Tasmania.

Dimensions.—Some important dimensions of 3 Tasmanian females, in *TLt*, are set out in Table I.

HETERODONTUS GALEATUS (Günther), 1870

Cestracion galeatus Günther 1870, Cat. Fish. Brit. Mus., viii: 416. Type locality: 'Australia' [= New South Wales, *fide* McCulloch (1929:4)].

Claim to inclusion in Tasmanian list.—This species is not included in any local list, nor is it credited to Tasmania by the Check List or the Handbook. However, Whitley (1940:73) notes, 'It has been dubiously recorded from Tasmania.'

I have received reports from several careful observers that suggest it may occur along our northern coast; but I have seen no specimens.

TABLE I

Heterodontus portusjacksoni (Meyer), 1793. Three Tasmanian females: (*a*) Deviot, Devon, February 1941, (*b*) Coles Bay, Glamorgan, 4th November 1958, (*c*) Low Head, Dorset, 25th January 1934. Actual dimensions in millimetres in first line: all other dimensions as thousandths of total length.

Dimension	Specimen								
	a			*b*			*c*		
Total length (mm)	724			896			962		
Snout	88			95			84		
Eye: horizontal diameter, interorbital distance	29	73		29	69		—	—	
Mouth: length to most anterior point, length to most posterior point, width	14	41	90	16	55	106	—	58	—
Gillslits I-V: lengths to slits	170	188	203	174	190	204	165	—	—
	217	229		217	229		—	—	
Gillslits I-V: lengths of slits	61	58	55	68	64	59	—	—	—
	46	26		51	37		—	—	
Pectoral: length to origin, base, greatest width	181	104	156	191	170	152	190	—	—
Pectoral: length of anterior border, outer border, inferior border	220	192	76	246	192	76	225	122	—
Pectorals: total spread of 2 fins	552			592			—		
First dorsal: length to origin, base, vertical height	276	84	99	271	83	95	276	81	—
First dorsal: length of anterior border, outer border, inferior border	146	104	59	134	85	57	125	92	63
Spine of first dorsal: total length, exposed length	83	32		65	20		47	35	
Second dorsal: length to origin, base, vertical height	554	70	83	553	69	73	555	67	—
Second dorsal: length of anterior border, outer border, inferior border	116	86	49	109	85	50	93	78	49
Spine of second dorsal: total length, exposed length	76	30		63	20		63	34	
Anal: length to origin, base, vertical height	624	48	—	628	49	50	624	56	—
Anal: length of anterior, outer border, inferior (inner) border	95	58	35	102	45	50	110	52	32
Pelvic: length to origin, base, total spread of 2 fins	417	86	214	428	84	227	425	—	—
Pelvic: length of anterior border, outer border, inner border	98	86	48	103	104	61	—	—	—
Caudal: length to inferior origin, superior origin	—	791		785	789		781	—	
Vent: length to middle	477			484			—		
Spiracle: length to anterior border, diameter, interspiracular distance	116	4.6	99	121	4.5	—	—	—	—
Spiracle: distance from middle of posterior border of orbit	—			22			22		
Nostril: length to anterior border, length of aperture, internarial distance	73	19	10	69	19	13	—	—	—
Height: at top of supraorbital ridge, maximum (at gillslit V)	131	—		—	—		124	114	
Distance between supraorbital ridges (to outer edges)	91			—			85		

Family SCYLIORHINIDAE

Only two species, (1) *Cephaloscyllium isabella* (Bonnaterre) 1788—dealt with below as *C. i. laticeps* (Duméril) 1853—and (2) *Halaelurus analis* (Ogilby), 1865, are credited to Tasmania in the Check List. The first occurs in southern New South Wales, Victoria and South Australia; the second in these States and in Western Australia.

There have since been added both the 2 species previously known from the southern mainland States, thus leaving of the 6 Australian members of the family only 2 unreported from Tasmania, namely, *Halaelurus labiosus* (Waite), 1905 from Western Australia, 'also doubtfully recorded from Queensland and Northern Territory' (Munro, 1956:6), and *Atelomycterus macleayi* Whitley, 1939, from Queensland, Northern Territory, Western Australia. Species added to our list since 1929 are: (3) *Galeus boardmani* (Whitley), 1923, a female (previously males only known), *Lt* 503, caught in 300 fathoms off Maria Island on 2nd July 1952, recorded by Olsen (1958:156); (4) *Halaelurus ..vincenti* (Zeitz), 1908, a specimen, *Lt* 462, caught in a graball net in George Bay, near St. Helens, Dorset/Cornwall, in May 1951, recorded by Olsen (1958:156). In reporting (4) Olsen gives some valuable comparative comparative measurements of two examples of (2) and one of *Parascyllium ferrugineum* McCulloch, 1911 (in text species inadvertently attributed to Waite), the last-named being in the same paper recorded for the first time from our waters [Tasmanian species of Orectolobidae keyed in a paper in the present series (1961)].

KEY TO SCYLIORHINIDAE RECORDED FROM TASMANIA

1 { A series of enlarged denticles along upper edge of caudal, and a series along lower edge of caudal peduncle. Base of second dorsal > base of first dorsal .... *Galeus boardmani*
Neither of two such series of enlarged denticles present. Base of second dorsal ≤ base of first dorsal 2

2 { Two gillslits over pectoral base. Base of first dorsal partly (≒ ½) over pelvic base; interdorsal < 1½ (0.7 — 1.1) base of first dorsal. Anal base ≤ (0.7 — 1.0) first dorsal base; the fin ending under posterior half of second dorsal base. With large dark bars and blotches on dorsum and upper half of lateral surface; and with smaller dark spots. *Cephaloscyllium isabella laticeps*
One gillslit over pectoral base. Base of first dorsal wholly (or virtually wholly) behind pelvic base: interdorsal > 1½ (2-3) base of first dorsal. Anal base > (1.5-2) first dorsal base; the fin ending under anterior half of second dorsal base. Without large dark bars and blotches on dorsum or upper half of lateral surface; with smaller spots only 3

3 { Anal base about 2 first dorsal base. Length from end of second dorsal base to end of caudal about 1½ in length from tip of snout to origin of first dorsal (or twice the first distance equal to distance from tip of snout to about middle of interdorsal). Pelvics of male connected by a membrane behind the claspers. Light brown with widely spaced dark rusty spots *Halaelurus analis*
Anal base about 1½ first dorsal base. Length from end of second dorsal base to end of caudal about 2 in length from tip of snout to origin of first dorsal (or twice the first distance equal to distance from tip of snout to about first dorsal base). Pelvics of male in contact behind the claspers. Dark brown with numerous small white spots .... *Halaelurus vincenti*

Genus CEPHALOSCYLLIUM Gill, 1862

CEPHALOSCYLLIUM ISABELLA LATICEPS (Duméril), 1853

(Fig. 1)

Squalus isabella Bonnaterre, 1788, Tabl. Encycl. Meth., Ichth.: 6. Type locality: La mer du Sud.

Scyllium laticeps Duméril, 1853, *Rev. et Mag. Zool.* (2), v: 11 and 84, pl. iii, fig. 2 (head). Type locality: Coasts of New Holland (Verreaux) [= Tasmania, *fide* Whitley (1940)].

Cephaloscyllium isabella (Bonnaterre). McCulloch, 1929, *Mem. Aust. Mus.*, v, 1: 9.

Cephaloscyllium laticeps (Duméril). Whitley, 1940, Fish. Aust., pt i: 92, fig. 8, 1.

? *Cephaloscyllium laticeps* forma *nascione* Whitley, 1932, *Rec. Aust. Mus.*, xviii, 6: 323, fig. 2, 1. Type locality: off Montagu Island, New South Wales.

Cephaloscyllium isabella laticeps (Duméril). Munro, Handbk Fish. Aust., 3: 6, fig. 38 [in *Fisheries Newsletter*, xv, 7, July 1956: 18, fig. 38].

Remarks.—The Australian Swell Shark is now generally regarded as distinct—either specifically, as, for example, by Whitley (1940), or subspecifically, as, for example, by Munro (1956)—from the New Zealand form, the latter being said to have anal base equal to distance between anal termination and origin of lower caudal lobe, whereas in the Tasmanian shark the fin base exceeds the other dimension. Again, New Zealand examples are said to be larger, reaching 8 feet, with a mean length of about 3 feet; while for the Australian form Whitley notes 'Length usually about one foot, but a Tasmanian specimen measured 38 inches': all adults I have seen were about 3 feet in total length, none reaching 4. Within the Australian species or subspecies, a forma, *nascione*, based on an example from New South Wales (Whitley, 1932) has been described: this is noted as being lighter-colored and as exhibiting differences in form and position of fins, shape of nostrils, and other features.

The type locality of Duméril's species, recorded, *teste* Verreaux, simply as Coasts of New Holland, has been more precisely located (Whitley, 1932) as Tasmanian waters. As a contribution to our

knowledge of this species, for local (and it now appears, topotypical) examples of which no detailed dimensions seem to be available, some measurements of 3 adult males and 4 adult females, and one young with egg-sac attached are here offered, together with some general observations.

Material.—The 7 adults, arranged in descending order of *Lt*, are: (*a*) female, *Lt* 961, found dead on beach by writer, Ulverstone, Devon, 4th August 1933; (*b*) female, *Lt* 930, George Town, Dorset, Mr C. Andrews, July 1939; (*c*) female, *Lt* 919, caught, with bare hands, by Dixon Hinch among rocks of breakwater, Ulverstone, Devon, 19th May 1960; (*d*) female, *Lt* 907, speared, at moderate depth, off rocks at lighthouse point, Low Head, Dorset, by Mr J. Turner, 3rd November 1957; (*e*) male, *Lt* 895, same history as (*b*); (*f*) male, *Lt* 894, speared by Mr R Lee in about 10 feet of water, hidden in weed with only the region behind the second dorsal exposed, Low Head, Dorset, 1st December 1957; (*g*) male, *Lt* 885, caught by Mr W. J. Beaumont at Penguin, Devon, in a graball net about 40 yards from the beach, very close to the rocks, 18th June 1933. The material is, it will be observed, rather restricted geographically, being confined to a stretch of our northern coast extending, in a direct line between the eastern terminal at Low Head and the western at Penguin, for less than 40 miles: except for George Town, about 4 miles inside the wide estuary of the Tamar, localities are on the open coast.

The egg-case containing a young shark, *Lt* 115.5 with yolk sac attached, was found among seaweed on the beach at Falmouth, Cornwall, by Miss Joanne Benson on 1st November 1959. When received, the specimen, after several days' exposure, was somewhat desiccated: however, the embryo had suffered a rather suprisingly small amount of general degeneration, perhaps the most marked effects being some considerable drying-out of the caudal and the loss of the contents of the yolk sac. On receipt, the embryo was removed from the egg-sac, and both were placed in alcohol.

Weight.—Specimen (*d*) immediately after capture weighed 10 lbs.

Proportions, Tlt.—A number of proportions of the 8 specimens are set out in Table II.

In view of the diagnostic significance of the relative sizes of anal base and distance of anal from lower caudal origin the actual dimensions may profitably be recorded. Anal base, 72, 62, —, 71, 68, 67, 66, foetus 9.0; termination of anal to origin of lower caudal lobe 46 57, —, 44.5, 45, 51, 37, foetus 7.5. Thus in the 6 adults for which data are available the base is 1.1-1.7, mean 1.47, times the other dimension: in foetus 1.2.

The *Lt* range of adults is too small to provide reliable evidence of systematic variation of size of regions and structures relative to overall size of shark, if such variation exists. It will be seen from the table that the great majority of variates are tolerably constant in value. For the important morphological items, lengths to origins of pectoral, pelvic, first dorsal, anal, second dorsal, lower caudal lobe the coefficients of variation of the absolute dimensions (not proportional values in table) are 4.5 ± 1.2, 4.1 ± 1.1, 3.4 ± 0.9, 3.2 ± 0.8, 2.6 ± 0.7, 2.8 ± 0.8—which are of the expected order of magnitude for an adult sample in which (as appears to obtain here) there is no marked sexual dimorphism. Compared with adults the foetus has a relatively smaller pectoral and first dorsal; and does not exhibit the high values for girth between pectoral and pelvic that are so characteristic of the adult Swell Shark.

Teeth.—In (*a*) the teeth in the lower jaw are in up to 6 rows: in the median anteroposterior line are 5 very small teeth; laterad, those of the next line fairly small; third line with largest teeth; thereafter regularly decreasing in size laterad: in upper jaw 5 or 6 rows; the median line largest, the rest gradually and regularly decreasing in size laterad. Two typical examples of the larger teeth of this specimen are shown in fig. 1. It will be seen they differ noticeably from those of the Tasmanian example and of the forma *nascione* as depicted by Whitley (1940, fig. 85, 1b, 2b); particularly by the presence here in the tooth from the upper jaw of an additional pair of cusps. Specimen (*f*): in upper jaw teeth in about 5 rows; curved dentigerous band on either side with a maximum anteroposterior extent of 9 mm and a chord of 66.9; the two bands just contiguous mesially (though the most closely approximated teeth here are 3 mm apart); in lower jaw in 4 rows, the chord 59.6, the slightly elevated platforms of the dentigerous zones failing by 5 to meet mesially. Specimen (*d*): in about 4 rows in either jaw; maximum width (anteroposterior) of band in upper jaw 5; toothed regions fail to meet in upper by 2, in lower jaw by 6. Immediately behind the tooth-bearing band there lies, in either jaw, a somewhat similarly shaped, but rather wider, frenum covered with numerous closely-set low white mounds, rather larger in lower jaw, where they mostly exceed in size the largest tooth. Unlike the dentigerous arcs, the frenum is wholly continuous across the middle line; though there are present, in the lower jaw only, two small ovoid patches devoid of the mounds—these lie behind the most internal teeth, their posterior borders constituting part of the hind margin of the frenum. The floor of the mouth is smooth; the palate almost smooth, with some faint transverse ridges. Tongue white, smooth below; upper surface with some projections that tend to assume the form of small knobs anteriorly, of ridges posteriorly.

Dermal denticles.—Their degree of development shows considerable variation in different individuals and in different parts of one individual. In some specimens there is a pronounced shagreen feel: in others, for instance (*f*), the general surface of the shark is surprisingly smooth, and in most portions of the animal much the same sensation is felt whether the hand is passed backwards or forwards along the skin; the nearest approach, in (*f*), to anything in the way of erect or suberect projections being met with on the side of the throat. The denticles vary markedly also in form, and elongate somewhat curved spines such as those figured for this species (Whitley, 1940, fig. 85, 1c, 2c) may be wholly lacking. It seems evident the whole matter of denticles calls for further study. For pattern of enlarged denticles in embryo, see below.

Egg-case.—There was for some time confusion as to which of the egg-cases commonly found cast up on the shore was rightly associated with this shark. A smooth case, narrowest at about one-sixth of its length, figured by Whitley (1940, fig. 29, No. 8) as '*Cephaloscyllium* (?) from Tasmania' does not belong to this species; the '"laminated" egg from Victoria' illustrated in fig. 30, No. 30 does: elsewhere in this volume the matter is cleared up by the entry (p. 92), 'Mr H. M. Hale records "laminated" eggs as having been laid by South Australian specimens in March, 1929'. Confirmatory Tasmanian records were obtained in 1939 when eggs of this type (for which, it may be remarked in passing, 'laminated' does not seem to be a happy term: the notable feature is the presence of well-developed wavy obliquely-set ridges on the case) were taken from specimen (*b*).

The following notes were made when 2 ova, in their cases, were dissected-out from specimen (*d*). Wall of oviduct, when cut through, appeared to consist of two layers that tended readily to separate. Egg-cases were opened and an unsuccessful attempt made to 'pour' yolks into formalin (fixation should have been carried out *in situ*). Case filled with pale yellow yolk and colorless, fluid but viscous albumen. As the case was being removed from oviduct, the tendril or byssus continued to be released as an uncoiled thread that appeared to extend right up to the oviducal gland; on exposure to air it soon assumed a helical form. Color of cases, deep cream. Egg-case (α): tendrils at both ends of case very pale yellow; at broader end 1670 long; at pointed end one tendril 820, other 669 (but elastic): length of case 112, maximum width 50, width at wider end 31: ridges number 31 on one face, 33 on other, with some anastomosis, particularly near wider end. Egg-case (β): tendrils pale yellow at broad, very pale at narrow, end; at broad end 1750 long, at other end 870, 930 (but all elastic): ridges number 31, 33, with some anastomosis terminally: length 111, maximum width 49, width at wider end 31. On being placed in formalin, the cases became bluish.

The case from which (*h*) was taken is of the usual dark yellowish horn color: length 111, maximum width 48.5, width at wider (squarer) end 33.5, at narrower end 15: on either face 24 ridges of which 19 are continuous in an undulating oblique course from one longitudinal border to the other, the rest failing to extend uninterruptedly from one side to the other either merely because they are too short, or else because they become fused (typically about midway between the borders) with an adjoining ridge, the former situation commonly arising near the ends, the latter near the middle of the length, of the egg-case. At either lateral margin the longitudinal bounding strip of the case appears as a convex band, with a maximum width of about 4, on one surface and as a groove on the other surface; the two convex bands being on different surfaces. From the narrow end this strip continues as a coiled tendril, some 400 long when roughly straightened out; basally, where it is somewhat depressed, it is about 2 wide: distally, becoming more nearly circular in section, it tapers to a fine point. Of this pair of tendrils, one bears 5, the other 2, greyish subcylindrical hydroid incrustations, of which the longest measures 12, the shortest 4. No tendrils remain at the broad end of this specimen.

Testes.—The testes of (*f*) were whitish, with red mottlings. One measured 110 x 45 x 20, the other 110 x 47 x 27.

Stomach contents.—The stomach contents of (*d*) were the beak of a squid, with portion of the muscle of the mouth region attached, and parts of a fish skeleton. In (*f*) the only recognizable items were 2 sets of smallish cephalopod beaks.

Foetus.—Some notes on the foetus from Falmouth (fig. 1), the circumstances of the finding of which have already been noted, are given below.

(*i*) *General form.*—The great width of the head that characterizes this species is very evident, the maximum width (19.4) occurring, as usual, between spiracle and first gillslit. This is the greatest width of the specimen, the usual expansion of the early part of the trunk not being developed, width at end of pectoral base (12.5) being only 0.6 of maximum width of head (contrast about 1.1 in adult). Behind head, width decreases rapidly and evenly to become at origin of first dorsal about one-third of initial value; thereafter more slowly, being at origin of upper caudal lobe about half value at first dorsal. (*ii*) *Fins and finfold.*—Much-dwindled remnants of the finfold are traceable. On ventral surface: anteriorly as a low ridge, rapidly decreasing in height cephalad, from anal base for a distance subequal to base of fin, *i.e.*, about halfway to anterior border of vent; immediately behind anal, disappearing for a distance of rather less than half fin-base, and, on reappearance, quickly developing to form a triangular flap, slightly more than 1 mm deep, immediately prior to origin of lower caudal lobe. On dorsal surface: first becoming evident at a point less than length of first dorsal base behind that fin, and continuing to origin of second dorsal; beginning again less than 2 behind that fin and continuing backward uninterruptedly to become confluent with upper caudal lobe—quite low throughout its length, reaching its greatest height as it approaches caudal. The outlines of vertical fins do not differ greatly from those of adult: however, the caudal, the posterior two-fifths of which is sharply upturned, presents, anterior to the notch, a ventral profile having a single boldly convex sweep, instead of being constituted of two line segments meeting at an obtuse angle. (*iii*) *Denticles.*—A most interesting feature of the specimen is the presence on the back of paired series of enlarged denticles not found in the adult (enlarged denticles along mid-dorsal and mid-ventral lines, behind dorsals are, it may be recalled, a normal character of *Galeus boardmani* (Whitley), 1928). Beginning a little to right of median line of dorsum, at level of 5th gillslit, a row of 32 denticles extends back for 32 mm to end a trifle beyond first dorsal origin: at an equal distance to left of median line is a series of 34, one in advance

of first of right row, and one behind last of that row. Anteriorly the rows are 4.1 mm apart, posteriorly 3.1, with a closest approximation, at about 22nd pair of denticles, of 1.9. Denticles are of almost uniform size, about 0.6 long, sloping backwards, outwards at about 45° to anteroposterior axis of animal, and slightly upward. From above each is more or less oval in outline, the proximal end the wider, but the distal not sharply pointed; external surface fairly convex transversely: anterior two-thirds opaque white, rest translucent. Viewed laterally, denticle presents, first a white broadly attached base, the upper profile of which is strongly convex; secondly, a distal blade, with straight or slightly concave upper profile. Some of the denticles are seen to be provided with (and possibly all possess) an elongate, slender, distally expanded pedicel (fig. 1 *d*), lying partly, or wholly, embedded in the integument, cephalad of the exposed portion. About two-thirds of first dorsal base behind that fin, are found, on right, 2 similar denticles: on left, 3 occur behind the fin, second in line, transversely, with first of right-hand series, third at one normal interval behind level of second on right. Near tip of caudal are found, on left surface, two rows of small nodular, or obscurely stellate, denticles closely flanking the notochord; upper row, extending forward from fin-top for 6 mm, consists of 20, lower row, which is slightly shorter, of about 15: on right surface each row consists of about 17.

[The above notes were written in 1961. While in Rome in 1962 I observed street fish-stalls often carried a shark broadly similar in general facies to, but somewhat larger than, our Swell Shark: examination of unskinned specimens revealed the presence along the midline of the dorsum of about a score of specialized denticles of the same general form as those of the present embryo, but arranged in a single row, and of course considerably larger. (This shark, the *plombe* of the dealers, was sold in slices at 100-150 lire per etto, approximately 6/4-9/6 a lb). All the evidence would suggest the presence of these denticles involves retention of a primitive feature.]

(*iv*) *Yolk sac.*—At its insertion the yolk stalk develops a longitudinal fold some 5 long, its anterior insertion being level with first gillslit: at a few millimetres distant from the body it contracts to become a thin cylinder, about 1.5 in diameter, and is, in all, 22 long. The yolk sac, which has become somewhat shredded and shrivelled and has lost part of its walls and virtually all its contents, has, as preserved, a length (at right angles to ventral surface of foetus) of about 25, and a width of about half this. Walls thin, smooth, translucent, not macroscopically structured: at base of bag a few yellow granular masses of yolk. (*v*) *Coloration.*—Ground color on ventral surface in advance of pelvics white, behind pelvics pale yellowish brown: on dorsal surface of head chiefly yellowish brown; of trunk warm yellowish brown: on dorsal surface of head (except region of gills, which is white) yellowish brown; of trunk mostly whitish, somewhat darker above. Pigmentation is already well advanced. On dorsal surface are well-marked paired postorbital blotches; and more or less complete saddles, of from moderate to dark (at times almost blackish) brown, on occiput, at level of adpressed pectoral, flanking each dorsal base, and at upper origin of caudal. All these extend, to a greater or lesser extent, on to lateral surface; which also bears its own separate markings, in particular a strong patch above and behind gills, another, smaller, shortly behind it, some subvertical brownish streaks (on right only) between last marking and level of pelvic origin, small spot above pelvic base. Pectoral with a dusky blotch covering most of left fin, outer and hinder half of right. First dorsal almost wholly dusky. Second dorsal obscurely clouded, least so externally; a dark smear along base. Anal unpigmented. Caudal briefly dark at upper origin; mostly more or less uniformly greyish, with some darker clouding in basal two-thirds of lower lobe in its anterior one-third, or more. Pelvic with dark blotch near middle. (*vi*) *Sex.*—There are no signs of claspers.

Behaviour.—Whitley (1940:92) observes of this shark, 'It can live more than one day out of water'. Specimen (*a*) netted at night was forwarded next day by train to the Queen Victoria Museum Launceson. While the teeth were being examined at about 4 p.m., the mouth on two occasions closed tightly and remained so for a short time. Water was then dashed on the head and the shark began to breathe. On being placed in a tank of water it continued to exhibit breathing movements while left there (for a quarter of an hour), and also moved caudal and pectoral: it did not, however, fully recover.

Mr. Lee reported the general behaviour of (*f*) was sluggish: after being speared in the spine it offered no resistance. Specimen (*d*), secured during an excursion of the Northern Tasmanian Subaqua Club, was placed, still alive, in a rock pool. While lying partly on its side, with the tip of the snout at times projecting out of water, it expelled water from the gills about 28 times per minute, the current being traceable over some two-thirds of the pectoral base.

Breeding season.—As already noted, H. M. Hale's record of egg-laying by this species is for March; this is the month in which our foetus (*h*) was collected. On the other hand, egg cases were taken from (*b*) in July and from (*d*) in November. While this paper was in course of compilation, Michael Horne forwarded to the Queen Victoria Museum, Launceston, a fresh egg-case, with contained ovum, found washed up on Grant's Beach, Devon, on 24th September 1961. Like those taken from (*d*), it is cream colored, noticeably different from the characteristic horn color of beach-dried specimens.

A similar wide range of dates is recorded for another member of the family, *Halaelurus vincenti* (Zeitz), 1908, Whitley (1940) noting (*a*) a male foetus trawled by the *Endeavour* in the Great Australian Bight in March, and (*b*) two shelled ova taken by H. M. Hale from a specimen caught in St Vincent Gulf, South Australia, in September.

TABLE II

Cephaloscyllium isabella laticeps (Duméril), 1853. Eight Tasmanian adults and one foetus (localities in text). Actual dimensions in millimetres in first line: all other dimensions expressed as thousandths of total length

Dimension	Adults							Foetus
	a ♀	*b* ♀	*c* ♀	*d* ♀	*e* ♂	*f* ♂	*g* ♀	*h* ♀ ?
Total length (mm)	961	930	919	907	895	894	885	115.5
Eye:								
Length to eye	47	55	—	56	48	48	62	74
Diameter of eye	32	40	—	25	32	30	38	33
Length to anterior margin of orbit	—	—	—	48	—	44	—	62
Length to posterior margin of orbit	—	—	—	82	—	81	—	99
Mouth:								
Length to midpoint of free margin of upper lip	31	36	37	34	32	35	49	43
Length to midpoint of upper margin of lower lip	—	—	—	45	—	43	—	51
Length to angle of gape	—	87	93	86	85	—	—	97
Width inside lips	115	118	—	121	115	76	—	72
Width including labial fold	—	132	—	128	130	85	135	82
Nostril:								
Length of anterior margin	—	28	26	25	22	16	—	25
Length of posterior margin	—	35	36	33	34	32	—	35
Total oblique extension	—	19	—	—	20	—	—	18
Internarial	31	33	—	35	32	23	—	18
Shortest distance, nostril to mouth	—	7.5	—	—	8.9	—	—	8.7
Spiracle:								
Length to anterior margin	—	86	—	85	87	84	—	105
Length	5.2	6.5	—	8.0	8.5	7.0	5.6	7.8
Interspiracular	89	94	—	100	92	96	97	120
Shortest distance, spiracle to orbit	11	11	—	12	12	12	5.6	5.2
Gillslits:								
Length to I	148	141	—	144	144	141	144	161
Length to II	—	155	—	—	158	—	—	—
Length to III	—	165	—	—	168	—	—	—
Length to IV	—	175	—	—	178	—	—	—
Length to V	—	184	—	193	189	178	—	217
Length of I	—	32	—	35	37	38	—	—
Length of II	—	34	—	34	35	28	—	—
Length of III	—	30	—	33	34	26	—	—
Length of IV	—	28	—	30	33	23	—	—
Length of V	—	22	—	19	22	18	—	—
Pectoral:								
Length to origin	184	168	171	180	170	175	142	203
Length	142	180	—	—	172	—	160	123
Base	87	97	—	—	104	—	107	78
Length of border, anterior	—	—	—	181	—	179	—	122
Length of border, outer	—	—	—	145	—	157	—	104
Length of border, posterior	—	—	—	73	—	65	—	43
Maximum width	137	151	—	—	142	—	132	104
Width at middle of length	—	123	—	—	101	—	—	97
Total spread of 2 fins	376	—	—	458	—	465	452	312
First dorsal:								
Length to origin	503	516	515	491	525	493	512	476
Base	78	96	99	100	79	90	78	60
Length of border, anterior	—	118	—	126	107	110	—	69
Length of border, outer	—	70	—	71	61	65	—	48
Length of border, posterior	—	24	—	26	23	25	—	35
Vertical height	—	73	—	79	69	77	—	61

TABLE II—*Continued*

Dimension	Adults							Foetus
	a ♀	*b* ♀	*c* ♀	*d* ♀	*e* ♂	*f* ♂	*g* ♀	*h* ♀ ?
Second dorsal:								
Length to origin	669	669	690	667	686	671	683	618
Base	55	57	60	62	55	58	56	62
Length of border, anterior	—	—	—	69	—	67	—	69
Length of border, outer	—	—	—	43	—	39	—	39
Length of border, posterior	—	27	—	28	25	25	—	30
Vertical height	—	39	—	42	37	41	—	36
Anal:								
Length to origin	649	654	655	640	643	635	662	608
Base	75	67	—	78	76	75	75	78
Length of border, anterior	—	—	—	96	—	95	—	82
Length of border, outer	—	—	—	41	—	39	—	34
Length of border, posterior	—	—	—	25	—	25	—	22
Vertical height	—	—	—	—	—	—	—	39
Pelvic:								
Length to origin	438	481	473	464	465	439	498	423
Base	91	94	—	—	89	—	85	70
Length of border, anterior	—	81	—	72	85	78	—	43
Length of border, outer	—	—	—	88	—	97	—	87
Length of border, inner	—	41	—	28	63	41	—	36
Vertical height	—	53	—	—	61	—	—	36
Total spread of 2 fins	—	—	—	152	—	169	—	95
Caudal:								
Length to origin of lower lobe	772	782	787	767	780	767	769	750
Length to origin of upper lobe	—	798	810	788	799	788	—	796
Maximum depth of fin	81	96	—	96	89	96	90	95
Distance from (lower) origin to level of maximum depth	—	—	—	88	—	96	—	74
Depth at notch	37	45	—	41	40	40	44	61
Distance of notch from tip	—	63	—	68	61	55	—	48
Maximum depth behind notch	58	—	—	65	—	69	69	78
Direct distance from lower origin to lowest point	—	113	—	—	114	—	—	87
Direct distance from lowest point to notch	—	102	—	—	104	—	—	147
Length of terminal border	—	65	—	—	69	—	—	65
Vent:								
Length to origin	—	473	528	507	498	480	—	448
Length	—	—	22	—	—	15	—	27
Claspers:								
Length; external border (from basal fold)	—	—	—	—	79	81	—	—
Length; internal border	—	—	—	—	127	106	—	—
Diameter at base	—	—	—	—	70	—	—	—
Girth at specified level:								
Front of mouth	—	—	—	—	—	213	—	—
Front of orbit	—	230	—	288	232	244	—	176
Back of orbit	—	—	—	369	—	341	—	372
Gillslit I	—	—	—	397	—	373	—	336
Pectoral origin	—	387	—	413	340	394	—	—
End of pectoral base	—	—	—	430	—	405	—	260
End of adpressed pectoral	—	—	—	436	—	369	—	—
Pelvic origin	—	—	—	303	—	277	—	199
Middle of first dorsal base	—	185	—	—	187	—	—	—
First dorsal termination	—	—	—	179	—	173	—	165
Anal origin	—	—	—	147	—	152	—	—
Second dorsal termination	—	—	—	111	—	103	—	114
Origin of lower caudal lobe	—	94	—	95	84	97	—	107

TABLE II—*Continued*

Dimension	Adults							Foetus
	a ♀	*b* ♀	*c* ♀	*d* ♀	*e* ♂	*f* ♂	*g* ♀	*h* ♀ ?
Width (first entry) and depth (second entry) at specified level:								
Front of nostril	—	68	—	—	70	—	—	85
	—	—	—	—	—	—	—	20
Front of mouth	—	—	—	79	—	78	—	94
	—	—	—	52	—	32	—	29
Front of orbit	—	—	—	127	—	106	—	90
	—	—	—	44	—	44	—	27
Middle of eye	—	114	—	—	122	—	—	121
	53	48	—	—	45	—	57	35
Back of orbit	—	174	—	171	154	148	—	147
	—	—	—	55	—	55	—	50
Gillslit I	—	—	—	171	—	157	—	156
	—	—	—	77	—	81	—	68
Pectoral origin	—	—	—	176	—	154	—	134
	—	—	—	88	—	97	—	71
Gillslit V	—	—	—	176	—	151	—	130
	—	—	—	92	—	110	—	72
Middle of pectoral	—	—	—	—	—	—	—	129
	145	—	—	—	—	—	93	87
End of pectoral base	139	232	—	187	200	160	236	123
	—	95	—	86	88	115	—	80
End of adpressed pectoral	—	—	—	165	—	117	—	113
	—	—	—	105	—	101	—	71
Pelvic origin	83	—	—	110	—	87	116	85
	—	—	—	57	—	86	—	63
First dorsal origin	—	58	—	—	61	—	—	53
	84	77	—	—	86	—	76	59
Middle of first dorsal base	—	—	—	—	—	—	—	43
	—	—	—	—	—	—	—	52
End of pelvic base	61	—	—	—	—	—	57	43
	—	—	—	—	—	—	—	55
End of first dorsal base	—	—	—	57	—	59	—	39
	—	—	—	51	—	48	—	54
Anal origin	—	—	—	47	—	47	—	35
	—	—	—	36	—	43	—	51
Second dorsal origin	—	—	—	—	—	—	—	33
	55	—	—	—	—	—	45	50
End of second dorsal base	—	—	—	34	—	35	—	25
	—	—	—	—	—	27	—	43
Origin of lower caudal lobe	—	24	—	28	25	29	—	20
	—	30	—	33	29	26	—	42

Family MYLIOBATIDAE

The Check List and Handbook each give (*a*) *Myliobatis* Cuvier, 1816; (1) *M. australis* Macleay, 1881; (2) *M. hamlyni* Ogilby, 1911: (*b*) *Aetobatus* Blainville, 1816; (2) *A narinari* (Euphrasen), 1790. Whitley (1940) includes (1) and (2); replaces (3), the type locality of which is Brazil, by *A. punctatus* (Mikluoho-Maclay & Macleay), 1881, the type locality of which is the Admiralty Islands; includes (while noting it as a New Zealand form) *M. tenuicaudatus* Hector, 1877.

It is generally recognized that the three nominal species of *Myliobatis* in Australia and New Zealand are closely allied and difficult to distinguish. *M. hamlyni*, based on a unique holotype, may well be a juvenile of *M. australis*. The mesial dental plates of *M. australis* are stated to be fewer (about 11-12, as against 14) and relatively longer (*i.e.*, anteroposteriorly) than those of *M. tenuicaudatus*. See, *e.g.*, McCulloch (1914:86, fig. 3); and Whitley (1940), who brings together figures of dentition after Roughley, McCoy, Waite, McCulloch, and provides a reconstruction for *M. hamlyni*.

Genus **MYLIOBATIS** Cuvier, 1816

MYLIOBATIS AUSTRALIS Macleay 1881

Myliobatis australis Macleay, 1881, *Proc. Linn. Soc. N.S.W.*, VI, 2:380. Type locality: Port Jackson, New South Wales.

Material.—The 16 individuals here noted—1941: 1, 2, 3 (♂♂), 4, 5, 6, 7 (♀♀); 1952: 1, 2, 3 (♂♂), 4, 5 (♀♀); 1954: 1 (♂) 2, 3 (♀♀); 1958: 1 (♀)—were found lying on the beach in a fresh state in late December or in January—most (possibly all) having been netted and cast aside by holiday seiners. Specimen 1958: 1 came from Scott's Beach, at the mouth of the Clayton Rivulet, near Ulverstone, Devon; the rest from Ulverstone.

Sexual dimorphism.—In an earlier contribution (1942) it was suggested, on the evidence of measurements of disc-width in 7 individuals, that in this species, following the general trend among rays, females are larger than males. Data for 7 males and 9 females set out in Table III support this conclusion. It will be observed that among the four major measurements of length and width recorded in no case does the maximum male value equal the minimum female correlate, and the female means are all at least one-fourth again as great as the male. For the dimension for which all 16 values are available (disc-width) the difference of the means is highly significant ($t = 5.44$).

Color pattern.—It is usually stated that the greenish, olive, or sandy ground color of the dorsal surface of the disc is patterned with pronounced or indistinct blue blotches. Of the 16 individuals noted in Table III (and several other Tasmanian examples examined) only one, 1958:1, a female from Scott's Beach, near Ulverstone, Devon, showed any clear sign of blue. In this example each pectoral carried some two dozen bright blue irregular, mostly more or less ovoid blotches (major axis 10-105, minor 10-31; the largest blotch 105 by 30, the smallest (two) 12 by 10); though rather irregularly disposed, they included an adnumbration of three imperfect transverse proconvex arcs: the ground color was greenish dark putty, largely bronzed. The middle of the hinder half of the disc was occupied by a large subtriangular area of brownish, through the posterior half of which ran a median line of about ten partly confluent white spots.

Ventral surface chiefly dead white: at left angle a large subtriangular region of yellowish, narrowly margined externally in its anterior half with whitish; along left border, from near front of head to level of first gill slit, a narrowish dark brown band, extending over on to the dorsal surface; on right half of disc extensive blotching and mottling along most of, and just internal to, the margin; a mesial patch of pale yellowish on throat.

The tail is colored thus. Ventral surface: white for about 260 from base (length of tail from its dorsal origin 705, from its ventral origin 700); then for about 180 white, with dusky pale-purplish smudges becoming increasingly prominent; smudges then replaced by small dark brown marks, set in depressions in integument; last 100 or so very dark, with terminal 35 almost black. Lateral surface: mainly white as far back as ventral surface is, but superior portion anterior to level of spear (length to spear 107; length of spear 98, of which 77 is free, rest adnate) with some large greyish purple smudges; caudad of spear, superior half at first greyish purple with numerous punctate blackish depressions (0.2-1 in diameter), inferior half lighter; beginning to darken at same level as ventral surface. Dorsal surface bronzed purplish from origin to spine, thereafter at first following color of upper lateral surface, but darkening early, being almost black for terminal 200 or more.

Jaws.—Table IV presents some data on 4 Tasmanian examples. Jaw *A* is from specimen 1952:4 (♀); jaws *B, C, D* from 1952:1, 2, 3, respectively (♂♂). These jaws show considerable range in size (for intercondylar width $V = 22.8$); but the largest 3 individuals constitute a tolerably compact size-group (for intercondylor width $V = 8.2$). It will be seen there is good correlation between the cube of the intercondylar width and the weight, the value of the ratio of the latter to the former being, for the 3 complete jaws, almost constant, but showing a slight systematic decrease with decrease in jaw-size.

Mesial dental plates.—In Table IV the mesial dental plates are numbered from behind forwards: the loss of a plate at the hinder (internal) end of the series is usually obvious, whereas anteriorly such a loss, particularly if accompanied by a lateral breakaway, is not always readily and surely determinable. Points of special interest regarding these plates include the following. (*a*) The number (10-12) is on agreement with published accounts. (*b*) The absolute lengths (anteroposterior measurement) vary considerably in the one specimen; the greatest divergence usually occurring near the ends of the series (the total range for all plates being, for the 4 specimens, 1.6, 1.0, 1.5, 1.4 times the range of the middle 6 plates): between individuals the range is great, the largest mean being 2.04 times the smallest (however, with specimen *D* excluded, this value drops to 1.15: and the coefficient of variation for the remaining 3 specimens, $V = 6.5$, is probably a value expectable within a single year-class). (*c*) As might, indeed, be predicted from the morphological set-up, widths exhibit less relative variation than lengths ($V = 2.1$-3.0; against 8.6-20.8); here again the greatest divergence is found near the ends of the series (the range for all plates being, in the 4 specimens, 3.2, 4.0, 2.6, 3.1 times the range exhibited by the middle 6 plates).

Lateral Plates.—(*a*) *Conventions of specification.*—Let *A, B, C, D* be the 4 specimens specified in Table IV: let *a, b, c, d* denote 1st-4th plate row, counting outwards from mesial strip: let *r, l* mean right, left side of jaw: let i, ii, iii . . . xi be the within-row rank number, *i.e.*, the number in sequence of the plate, counting from before backwards: let *h, p, q, t* denote *h*exagonal, *p*entagonal, *q*uadrilateral, *t*riangular plates (or, in appropriate context, 6, 5, 4, 3 sides). Symbols in combination are used in the order in which they are listed above.

(*b*) *Number of rows.*—All specimens show 3 rows on each side (*D l* missing); except *A* which has *d r* (a quite exceptional arrangement).

(*c*) *Number of plates.*—The total number of lateral plates (including several that obviously have been present but are now missing) are: *A r* 39, *A l* 32; *B r* 24, *B l* 24; *C r* 27, *C l* 27; *D r* 29; mean 28.9 per side. There are most plates in *a* (*A, r, l* 11, 11; *B* 9, 9; *C* 10, 10; *D* 10, —). In

TABLE III

Myliobatis australis Macleay, 1881. Comparative measurements (mm) of 7 males and 9 females. Specimen 1958: 1 from Scott's Beach, at mouth of Clayton Rivulet, near Ulverstone, Devon; other specimens from Ulverstone

Dimension	Males								Females								
	Specimen							Mean (No. of specimens in parentheses)	Specimen								Mean (No. of specimens in parentheses)
	1941: 1	1941: 2	1941: 3	1952: 1	1952: 2	1952: 3	1954: 1		1941: 4	1941: 5	1941: 6	1941: 7	1952: 4	1952: 5	1954: 2	1954: 3	1958: 1	
Width of disc	814	780	850	870	838	819	840	830.1 (7)	1022	1050	975	866	1149	1105	1095	1200	975	1048.6 (9)
Total length	—	—	—	889	997	946	911	935.8 (4)	—	—	—	—	1213	—	1190	1111	1294	1202.0 (4)
Length to vent	—	—	—	470	470	432	442	453.5 (4)	—	—	—	—	673	—	635	573	615	599.0 (4)
Length to dorsal fin	—	—	—	597	559	537	604	575.8 (4)	—	—	—	—	774	—	762	689	705	732.5 (4)
Base of dorsal	—	—	—	48	35	35	47	41.3 (4)	—	—	—	—	58	—	59	48	45	52.5 (4)
Spread of pelvics: pulled taut	—	—	—	267	298	286	—	283.7 (3)	—	—	—	—	413	—	—	—	320	366.5 (2)
Spread of pelvics: as they lie	—	—	—	—	—	—	260	260.0 (1)	—	—	—	—	—	365	350	315	260	322.5 (4)

A and in *D r*, *b* = *a*; but in *B* and *C*, *b* starts at ii; while *c* starts always at *iii*, except for *A c l* and *D c r*, which start at ii (*A d r* extends from iii to x). In the present state of the material *A l* xi is missing in *a*, *b*, *c*; also missing is *B c r* ix; imperfect plates are *D b r* i and *D c r* ii.

Number of sides.—In comparisons in this section we shall normally consider only *a*, *b*, *c* in each specimen, express mention being made where appropriate of the inclusion in the discussion of *A d r*. In considering the 4 types of small lateral plates represented, as specified by the number of sides (6, 5, 4, 3), we shall look at the distribution of *h*, *p*, *q*, *t* first by specimens, secondly by rows, thirdly within rows.

For the 4 specimens pooled cases of *h*, *p*, *q*, *t* number 38, 58, 78, 22, respectively: mean number of sides 4.57. Individual entries range from 0 (*D t*) to 30 (*A q*); specimen means being 4.54, 4.00, 4.80, 5.19: the mode is *q* in *A* (30) and *B* (27); and *p* in *C* (23) and *D* (16).

The mean number of sides in a breakdown by rows shown an interesting pattern, decreasing progressively from *a* through *c* (and *d*), the sequence being maintained in each specimen: for pooled material we find 4.91, 4.61, 4.25, 3.50. This pattern holds good, not only for *r* and *l* pooled, but also (except in the one case of *C r*) for *r* and *l* considered separately. In view of the interest attachable to this state of affairs, regression equations of mean number of sides (*Y*) on row number (*X*) have been calculated. In each of the following 5 paragraphs are recorded these items: specimen letter: mean number of sides in *a*, *b*, *c* (with, in parentheses, values predicted by the regression equation): the regression of *Y* on *X*: *t*.

A : 5.19 (5.19), 4.66 (4.65), 4.11 (4.11) : $Y = -0.540\ X + 5.73$: $t = 94.80^{**}$.

B : 4.39 (4.38), 3.94 (3.96), 3.54 (3.53) : $Y = -0.425\ X + 4.81$: $t = 30.24^{**}$.

C : 4.85 (4.87), 4.83 (4.79), 4.69 (4.71) : $Y = -0.080\ X + 4.95$: $t = 2.31$.

D : 5.40 (5.43), 5.22 (5.17), 4.88 (4.81) : $Y = -0.260\ X + 5.69$: $t = 5.62^{*}$.

A, B, C, D pooled : 4.91 (4.98), 4.61 (4.59), 4.25 (4.26) : $Y = -0.330\ X + 5.25$: $t = 19.05^{**}$.

A, B, C, D, with *r* and *l* plotted separately (for *a*, *b*, *c*) and with *A r d* incorporated : 4.97 (5.00), 4.88 (5.00); 4.48 (4.55), 4.70 (4.55); 4.13 (4.13), 4.35 (4.13); 3.50 (3.68) : $Y = -0.435\ X + 5.42$: $t = 7.45^{**}$.

In dealing with the distribution, within rows, of *h*, *p*, *q*, *t* we consider, first, the size of runs of plates having the same number of sides, secondly, the distribution along the anteroposterior extension of the row of plates of a given number of sides. First, in *A* runs of *h*, *p*, *q*, *t* are 5, 3, 4, 3 (*r*) and 5, 2, 4, 2 (*l*); in *B* 1, 2, 7, 3 and 1, 2, 8, 3;

TABLE IV

Myliobatis australis Macleay, 1881. Counts, dimensions and proportions: lower jaw and teeth of 4 individuals from Ulverstone, Devon, Tasmania. Linear dimensions in millimetres, weight in grams

Count, dimension, proportion		Specimen A	Specimen B	Specimen C	Specimen D
Serial numbers of mesial plates present (numbered from behind forward)		1 — 12	2 — 10	1 — 11	1 — 12
Total weight of jaw with teeth		105.50	77.35	68.69	(15.00) (imperfect)
Intercondylar width		122.5	110.0	105.5	62.0
Ratio of cube of intercondylar width to weight		174.2	172.1	170.9	(158.9) (imperfect)
Total width of tooth series (at middle) in intercondylar width		2.3	1.9	2.2	1.6
Width of middle mesial plate		31.0	40.2	30.3	21.1
Combined width (at middle of series) of 2 sets of lateral plates		23.0	16.9	17.5	17.4
Combined width (at middle of series) of 2 sets of lateral plates in width of middle mesial plate		1.4	2.4	1.7	1.2
Lengths of mesial plates	Range	5.0 — 8.1	6.9 — 9.0	5.9 — 8.0	2.6 — 4.9
	$\bar{x}$	6.98 ± 0.26	8.01 ± 0.26	7.03 ± 0.21	3.92 ± 0.23
	σ	0.88 ± 0.18	0.69 ± 0.18	0.77 ± 0.15	0.80 ± 0.16
	v	12.7 ± 2.6	8.6 ± 2.6	11.0 ± 1.8	20.8 ± 4.2
Widths of mesial plates	Range	28.5 — 32.0	38.2 — 41.0	28.1 — 31.0	19.2 — 21.1
	$\bar{x}$	31.03 ± 0.27	40.38 ± 0.28	30.15 ± 0.23	20.54 ± 0.16
	σ	0.93 ± 0.19	0.84 ± 0.20	0.77 ± 0.17	0.55 ± 0.11
	v	3.0 ± 0.6	2.1 ± 0.5	2.5 ± 0.5	2.7 ± 0.5
Length of mesial plate in its width	Range	3.8 — 5.7	4.5 — 5.8	3.8 — 5.1	4.2 — 7.4
	$\bar{x}$	4.52 ± 0.16	5.08 ± 0.13	4.34 ± 0.14	5.46 ± 0.31
	σ	0.55 ± 0.11	0.40 ± 0.10	0.45 ± 0.10	1.08 ± 0.22
	v	12.1 ± 2.5	8.0 ± 1.9	10.5 ± 2.2	19.9 ± 4.1

in *C* 2, 3, 3, 1 and 6, 7, 2, 1; in *D r* 4,7,2,0. It will be seen that in *A* and *B*, *r* and *l* are much the same; while in *C*, *l* exhibits a much greater frequency of high side-numbers than *r*. The maximum run in a specimen is held once each by *h* and *q*, twice by *p*. *A* has altogether 57 (or 51 for *a*, *b*, *c*) plates participating in runs: for *a*, *b*, *c*, *B* has 39, *C* 40, *D* (*D r* only) 27. In any one specimen the largest (or an equal largest) run number occurs for the same side-value of plate in each lateral half of jaw (maximum in *A* is *h*, in *B q*, in *C l p* and in *C r p* and *q* jointly). Secondly, on examining the position within the row in which plates with various number of sides occur we note the following points. The modal rank numbers for *h*, *p*, *q*, *t* are v, vi, ix, i, respectively. However, probably a more significant formulation of the position is obtained by disregarding the 2 cases of xi represented in the material as preserved and grouping i with ii, iii with iv, and so on. This yields the following frequency distribution for the 5 classes so constituted: *h* 10, 13, 11, 4, 0; *p* 0, 13, 20, 19, 6; *q* 8, 15, 9, 14, 30; *t* 7, 3, 4, 7, 1. It will be observed that *h* has its mode in the second of these classes, *p* in the third, *q* in the fifth; with *t* bimodal at the first and fourth classes. Broadly, the pattern is: *t* appears 8 times (36% of its total occurrences) in the initial position (*i.e.*, at the beginning of the row; which is not necessarily, and in *c* never is, i) being in 7 of these occurrences solitary, in the other one of a pair; its frequency then decreases, increases behind middle of row, again decreases: *h* tends to occur early (has i = 3; while of the 8 cases in which *t* is initial, *h* immediately follows it in 3); *p* tends to occur later than *h*, and *q* (particularly in respect of its second, and main, massing) later than *p*. Formulating the position in terms of rank numbers we have, for all values pooled, h < t < p < q (mean rank number per plate 3.9, 4.8, 6.1, 6.8) *i.e.*, six-sided plates register a higher proportion of appearances in the anterior portion of the rows than other plates. This overall pattern is presented in both the individuals *A* and *B;* the same sequence for *h*, *p*, *q* is maintained in *D* (in which there are no *t* entries); while in *C* we find *h* and *t* transposed (there being, however, only 2 entries, both initial, for *t*; whereas there are 11, 23, 18 for *h*, *p*, *q*).

Family GONORHYNCHIDAE

Only one species, *Gonorhynchus greyi* Richardson, 1845; recorded from all Australian States and from New Zealand.

Genus **GONORHYNCHUS** Scopoli, 1777

GONORHYNCHUS GREYI Richardson, 1845

Rhynchana greyi Richardson, 1845, Ichth. Voy. *Erebus & Terror*: 44, pl. xxix, figs 1-6 and one text fig. Type locality: W. Australia.

Gonorynchus greyi Richardson. McCulloch, 1929, *Mem. Aust. Mus.*, v, 1: 52 (synonymy).

Gonorhynchus greyi Richardson. Munro, 1956, Handbk Aust. Fish.: 28, fig. 196 [in *Fisheries Newsletter*, xv, 12, December, 1956: 18, fig. 196].

Remarks.—Appears—*fide* Johnston (1883)—in Allport MS. Apparently not uncommon; but seldom reaches market. A specimen, *Ls* 324, *Lt* 366, from George Town, Dorset, shows some meristic values outside those commonly accepted and some proportions transgressing the limits of the Handbook specifications, namely: D.10 [*cf.* 12-14], A.8 [9], l. lat. 180 [145-175]; depth in *Ls* 7.5 [9-14.8]; head in *Ls* 4.9 [5-6.3].

None of the readily accessible figures—provided by Stead (1906), Waite (1921) [reproduced in Waite (1923)], McCulloch (1927) [reproduced, somewhat reduced, in the Handbook (Munro, 1956)]—gives a wholly satisfactory representation of the fish. General form: Stead's figure is too deep in postorbital part of head, and it exaggerates the concavity of the dorsal profile behind the dorsal fin (which is perhaps insufficiently indicated in the other illustrations); the preanal ventral profile is rather more characteristic in Waite's than in McCulloch's figure; Waite's fish has supraorbital contour unduly convex. Opercular margin, best depicted in McCulloch. Pectoral: in McCulloch fin inserted a trifle high; the oblique down and back trend of the fin base is most clearly seen in Stead (too nearly vertical in McCulloch), but the anterior border of the base is proconvex, not proconcave. Fleshy suprapectoral lobe: probably delineated but not certainly recognizable in Waite; in Stead shown shorter than is characteristic, and originating unduly far cephalad. Pelvic: inserted too high on flank in McCulloch; much too rounded at postero-external angle, and not straight enough along posterior border, in Stead. Fleshy suprapelvic lobe; unrecognizable in Waite, doubtfully represented in Stead, well shown in McCulloch. Dorsal: Stead shows external border of fin convex, Waite almost straight, McCulloch excavate, with last ray exceeding penultimate—our specimen (in which longest, 3rd, ray is 35 mm, 9th 16.5, 10th, last, 15) agrees best with McCulloch's figure. Anal: Stead has a pointed fin, which is certainly astray; Waite represents length of last ray as less than one-third, McCulloch as about two-thirds, length of longest ray—in our fish last (13 mm) is 0.45 of longest (3rd, 29), so that, with fin extended (artificially) as in McCulloch's figure, the posterior border comes in our specimen to approach much nearer to verticality than in the figured example.

Proportions, TLs.—In the light of the above remarks the chief proportions of the present specimen may profitably be recorded. Length to origin of: pectoral 201, pelvic 667, anal 832, dorsal 688. Base (between parallels) of: dorsal 88, anal 60. Length of: eye 43 (vertical diameter 32), snout 76, head 207, pectoral 159, pectoral base 37, pelvic 113. Interorbital 49. Depth at vent 83, maximum depth 133, depth of caudal peduncle 57; maximum width 115. Suprapectoral flap: length 94, width 17. Suprapelvic flap: length 74, width 11.

Family ECHELIDAE

All 3 Tasmanian species of *Muraenichthys* Bleeker, 1865 (our only local echelid genus), namely, (1) *M. breviceps* Günther, 1876; (2) *M. australis* Macleay, 1881; (3) *M. tasmaniensis* McCulloch, 1911, have come under notice in papers of this

series. The chief references are: 1936, first Tasmanian record of (2); 1953, key to Tasmanian species (misprint corrected in 1959 paper), description, and figure of head, of (2); 1957, linear regression in (1) of lengths of certain body regions on other regions conventionally treated in diagnosis as independent variables; 1961, account of specimen of (3). Olsen (1958:57) has noted the occurrence of (1) 'along the silty foreshore between Middleton and Gordon, D'Entrecasteaux Channel, where it is recognizable by the reddish brown color it reflects from underwater lights.'

Some observations on two individuals of (2) are made below, and a more satisfactory representation of the head of this species (*cf.* 1953, pl. on p. 164, fig. 2) is provided (fig. 2).

Genus **MURAENICHTHYS** Bleeker, 1865

MURAENICHTHYS BREVICEPS Günther, 1876 (Fig. 2)

Muraenichthys breviceps Günther, 1876, *Ann. Mag. Nat. Hist.* (4), XVII: 401.

Record.—Two specimens: (*a*) Low Head, Dorset; December 1960; Miss Anna Seager; dropped on sand by alarmed silver gull, *Larus novaehollandiae gunni* Mathews, 1912; *Lt* 439; (*b*) Derwent River at Long Point, Sandy Bay, Buckingham; 3rd February 1961; Mr D. H. Hobbs; speared—using 12-foot spear with light—in 6 feet of water; *Lt* 472.5.

Dimensions.—Nine dimensions of each of 6 individuals have been tabulated earlier (1957, Table II). Values of the same variates for the present examples (specimen (*a*) first) are: length to dorsal origin, vent (middle), anal origin 75.5, 164.5, 169.0; 84.5, 178.5, 181.5: head 39, 40.5: snout 7.8, 8.3: eye 2.3, 4.0: interorbital 5.0, 5.0: greatest depth 13.1, 16.1 (in both at middle of branchial basket: specimen (*a*) somewhat shrunken by preservation in too strong alcohol). Some additional dimensions are: oblique length of gillslit 2.8, 2.8; intergill space (direct) 7.9, 9.0; length from tip of upper jaw (which exceeds lower by 1.9, 2.0) to end of gape 13.4, 12.9, to end of oral slit 15.4, 15.3; length of maxilla 19.0, 19.0; depth (in parentheses width) at points specified (specimen (*a*) somewhat shrunken); front of eye 6.0, 7.1 (5.0, 6.9); back of eye 7.0, 8.5 (6.3, 8.1); end of oral slit 8.3, 11.3 (9.0, 8.9); gillslit 12.8, 15.5 (8.5, 11.5); dorsal origin 11.8, 15.5 (8.5, 13.0); vent 10.5, 14.8 (8.5, 13.5); middle of tail 9.1, 12.0 (7.9, 11.1). In (*b*) length of dorsal ray at level of vent is 70, at middle of tail (where it is equal to anal ray) 6.8.

Pores.—In (*b*) midlateral pores on trunk comprise 18 to dorsal origin + 29 to vent: on anterior half of tail 48; behind this point they become increasingly difficult to count, but there are at least 36. Pores of the head are located as shown in fig. 2.

Schmidt's index.—In a sample of 6 fish it has been shown (1957) of Schmidt's index ($S = \frac{Lv - Ld}{Lt} \times 100$, where Lv = length to vent, Ld = length to dorsal origin, Lt = total length) first, that is relatively stable (showing a variation of less than 3 units over an Lt range of 348.5 mm, or 3.07σ: $V = 4.9$, $V' = 5.5$); secondly, that it exhibits significant linear regression on Lt ($S = 0.007424\ Lt + 17.53$: $t = 4.73^{**}$: mean error of values predicted by this equation on observed values being 0.3 index units, or 1.3%). The incorporation of the present examples (for (*a*) $S = 20.27$, for (*b*) 21.16) does not compromise the validity of these two generalizations. Over the same Lt range as before the extremes of the index differ by 2.78 units, or 3.42σ: $V = 4.0$, $V' = 4.2$. The regression equation now is $S = 0.007531\ Lt + 17.47$: $t = 6.26^{**}$: mean error of predicted on observed values 0.2 units, or 1.2%.

The most direct of all metrical specifications of the relative location of insertion of dorsal, namely, length to dorsal origin as a function of total length, is given, for the 8 fish, by the equation $Ld = 0.1645\ Lt + 1.25$; $t = 30.66^{**}$: mean error of estimated values 1.4 mm, or 1.9%—*cf.*, for sample of 6, $Ld = 0.1605\ Lt + 2.07$; $t = 23.06^{**}$: mean error 0.8 mm, or 1.1%.

Coloration.—The following observations are based on (*b*). (*i*) *Tail.*—Except for posterior 60-65, which is more or less uniformly dark greyish brown, at times somewhat olivaceous, tail is sharply bicolor, the line of demarcation being the pore-row, here equidistant from dorsal and ventral profiles. The light areas are golden: at vent numerous minute brownish punctulations descend from the midlateral line for rather less than half the distance to the midventral line (the whole lower surface thus being immaculate); at middle of tail, area with punctulations has increased to become subequal on each flank to total ventral unpigmented area; finally, punctulations reach midventral line at about 60-65 in advance of tail-tip. (*ii*) *Trunk.*—Dark color (which is approximately the same dark greyish brown, tending towards olivaceous, as ground color of upper tail) descends below lateral line (which continually approaches dorsal profile cephalad) to an increasing extend cephalad: at gillslit we have from dorsal profile to pore-row 4 mm, thence to lower border of dark region 5.5, thereafter 6 light to ventral profile. Light color of lower flank and ventral surface is silvery in anterior one-third; behind which it passes first into ivory, then into pale yellow. (*iii*) *Head.*—Light color of lower flank continues forward to angle of gape, with some clouding on posterior part of branchial sac. In advance of posterior border of eye dark dorsal and upper lateral regions are somewhat lighter, more greyish, than corresponding parts of postorbital head. Whole lower jaw and inferior surface of rest of head whitish, in parts somewhat silvery. (*iv*) *Fins.*—Anal pale, ivory, immaculate. Dorsal almost white; a barely perceptible duskiness produced by rather sparse microscopic brownish punctulations.

In (*a*) the color pattern is susceptible of less satisfactory examination: so far as can be determined, it does not appear to differ radically from that of (*b*). However, the light ground color—except on the branchial sac, which remains yellowish—here closely approaches orange; while the dark ground colour is a shining warm reddish brown. Fins pale orange: anal immaculate, dorsal with microscopic dark pepperings as in (*b*).

Family OPHICHTHYIDAE

Of 11 members of the family recorded from Australia 2 only are known to occur outside Queensland, Northern Territory and Western Australia: (1) *Malvoliophis pinguis* (Günther) 1873 (in Check List referred to *Bascanichthys* Jordon & Davis, 1892), from southern Queensland, New South Wales, Lord Howe Island; (2) *Ophisurus serpens* (Linné), 1758, from New South Wales, Western Australia, Tasmania.

Genus **OPHISURUS** Lacépède, 1880
OPHISURUS SERPENS (Linné), 1758
(Fig. 3)

Muraena serpens Linné, 1758, Syst. Nat., ed. 10: 244 (ed. 12, 1766: 425). (Based on Artedi, gen. 24, syn. 41). Type locality: Southern European seas.

Ophisurus serpens Linné. Lord, 1923, *Pap. Proc. Roy. Soc. Tasm.*, 1922: 64. McCulloch, 1929, *Mem. Aust. Mus.*, V, 1: 68 (synonymy). Munro, 1957, Handbk Aust. Fish.: 47, fig. 330 [in *Fisheries Newsletter*, XVI, 5, May, 1957: 17, fig. 330].

[?] *Ophisurus novae-zelandiae* Hector, 1870, *Tr. N.Z. Inst.*, 2: 34, pl. iii. Type locality: Poverty Bay, New Zealand.

[?] *Leptognathus novaezelandiae* (Hector). Parrott, 1960, The Queer and the Rare Fish. of N.Z.: 58, fig. 16.

Occurrence in Tasmania.—At the end of a paper giving a general account of seven species of fish found in Tasmania Ogilby (1897 *a*) remarked, 'A specimen of eel forwarded for identification belongs to the restricted genus *Ophisurus*, but it is in such bad condition that the species cannot be determined. It may, however, be included in the Tasmanian catalogue as *O. serpens*.' Later he appears fully to have accepted the specific determination, stating in a footnote to a paper on a N.S.W. larval teleost (1897 *b*: 159), '*Ophisurus serpens* has been recorded once from Port Jackson, and it is found as far south as Tasmania, when I have recorded a specimen in very bad condition.' The first local list in which the eel appears is that of Lord (1923). Lord & Scott (1924: 37) observe 'As regards the right of this species to appear upon the Tasmanian faunal list, we know of no further records or specimens beyond the reference [*i.e.*, 1897 *a*] made by Ogilby'. In the Handbook (Munro, 1957), Tasmania is given, along with N.S.W., W.A., without comment.

In August 1956 the Queen Victoria Museum, Launceston, received for identification an ophichthyid, *Lt* 1144, secured in a lagoon near the mouth of the George River (lower portion of river constitutes part of boundary between Dorset and Cornwall). The specimen is pretty clearly the eel appearing in Australian lists as *O. serpens*.

Whether this Australian form is conspecific with the European *O. serpens*, or only closely allied to it, is a question to which, with the literature at my command, I am not in a position to return a definite answer. As a possible useful step towards arriving at a satisfactory conclusion, a general account of the present specimen—including a description and figures of the dentition—is given below.

General features.—Anal rays about 320, dorsal (count more reliable than that for anal) 490, of which 163 occur in advance of anal origin. Posteriorly dorsal and anal fan-out, forming what is in effect a substitute caudal fin: at about 35-40 rays (about 60-70 mm) from end of fin, dorsal rays, here 7 long, begin to increase in length, at first slowly, then more rapidly, reaching at about 13 rays (about 22 mm) from end of base a maximum length of 11, behind which they decrease rapidly in a bold, even curve. A similar, but less pronounced, change in size and shape of anal occurs opposite that in dorsal. Tail extends 16.5 behind dorsal, 15 behind anal, as stout stiff subconical (somewhat compressed; at anal termination 8.5 high, 7.5 wide) free tip, ending rather bluntly. Pectoral 11 (first, and last, ray unbranched); fully spread, its width 0.8 its length, the upper and lower borders linear for half length of fin, beyond which margin is evenly rounded: upper end of base level horizontally with upper end of gill opening, lower end level with about middle of vertical extent of gill opening. Gill opening restricted to side, the lower border continued back, almost horizontally, in a shallow curve, for about 10, its termination being almost vertically under posterior end of the downwardly and backwardly oblique pectoral base. Snout markedly convex anteriorly, flattening somewhat posteriorly. Interorbital gently convex. Eye without free border. Posterior nostril in upper lip, at half an eye-diameter in advance of eye. Anterior nostril apparently a short tube, nearly as wide as long; 12 from tip of snout, that is, opposite third large vomerine tooth, that is, in advance of posterior nostril by a distance subequal to that by which latter is in advance of eye; distance from border of upper lip subequal to its own length.

Proportions, TLt.—Length to: pectoral origin 82; dorsal origin and termination 133, 986; anal origin and termination 407, 987; vent (middle) 363. Length of: head (to gill opening) 76, snout 20, mouth cleft (from tip of upper jaw, which exceeds lower by 2.8 mm) 41, pectoral 17. Eye 6.6, interorbital 8.0. Depth (and in parentheses width) at: front of eye 12 (9.6), back of eye 16 (14), middle of head, 26 (24), vent 17 (17).

Dentition.—Dentary teeth: just inside lip, which is 3.5 mm behind tip of ovoid platform of under surface of upper jaw, 2 large subconical teeth, directed backward and slightly outward; 3 mm further back, a pair, rather stouter, pointing backward and outward; after an interval of 5 mm, a line, 26.5 long, extending back to angle of gape, of 43-44 small teeth, with bulbous base and sharp point, directed backward and slightly outward, the largest, occurring at about anterior one-third of the series, about twice size of hindmost. Premaxillary teeth: one small median; a pair, just inside lip, 2 mm from jaw-tip, slender, about 1 long, directed slightly backward (left missing); 3 mm back, a pair, about 1.2 long, stouter than preceding pair, 3 mm apart transversely, curved first outward then inward. Maxillary teeth: on each side a line, 23 mm long, of 41 teeth, beginning 8 mm behind last premaxillary tooth, largest near

middle of series, smallest at either end, base slightly swollen, curved, directed backward, and vertically down or slightly inward. Vomerine teeth: series beginning 2 mm behind level of end of maxillary set; comprising, first, in a distance of 14 mm, 6 spaced teeth, the anterior 2 small, closely set, all 6 conical, stout, the largest about 2.5 long and largest in mouth, directed backward; secondly, beginning 3 mm. behind last tooth of preceding set, 14 small teeth in 15 mm (unless mouth is flattened by pressure, these lie hidden where 2 palatal folds meet in a pronounced median groove).

Coloration.—Head: dorsum dark brown, darkest anteriorly; laterally, below level of eye mostly dark grey with some brownish punctulations, above this more or less uniform dark brown in anterior half of postorbital extent, with posterior half crossed by about a dozen narrow, slightly sinuous longitudinal streaks of dark brown, subequal in width to their biscuit-colored interspaces; lower jaw dark greyish near gape, elsewhere greyish with considerable (anteriorly, very marked) brown; under surface dirty brownish grey. Trunk: back and upper sides dark olivaceous brown with coppery lights, the color passing, on lower flank, fairly rapidly, but without any sharp line of demarcation, into the rather lighter brown, with some silvery sheen, of the ventral surface; usually a distinct narrow darkening along pore-line. Tail: in general much like trunk, but, proceeding caudad, the dark olivaceous brown of the flanks extends progressively lower, finally leaving no noticeable difference between ground color of lateral and ventral surfaces; general color tends to darken caudad, but becomes somewhat lighter (with some patches of distinctly lighter brown on midflank) in last 60-70 mm. Dorsal and anal rather pale brownish grey, darkening somewhat in outer one-fourth, the outer one-sixth with a conspicuous dark, almost black band: towards posterior end of fin, membrane tends to become increasingly punctulated with with brown. Pectoral dark olivaceous brown.

Family SYNGNATHIDAE

Since the publication in contribution X of this series (1961) of a key to, and conspectus of, Syngnathidae recorded from Tasmania, which set forth a synoptic account of available knowledge on the local members of this family, several additional items of data have come to light: these are noted below.

Genus **LEPTONOTUS** Kaup, 1853

LEPTONOTUS SEMISTRIATUS Kaup, 1856

(Fig. 4)

Leptonotus semistriatus Kaup, 1853, *Arch. Naturges.*, xix, 1: 233—*nomen nudum.*

Leptonotus semistriatus Kaup, 1856, Cat. Lophobr. Fish. Brit. Mus.: 48. Type locality: 'Origin not noted' = S. Australia [*fide* McCulloch (1929: 85)].

Leptonotus verreauxianus Duméril, 1870, Hist. Nat. Poiss., ii: 573. Type locality: Tasmania (Verreaux).

Remarks.—Though Johnston (1882) and Lord & Scott (1924) observe this pipefish is not uncommon, I could not in 1939 find an example in a Museum collection, and in providing a re-description and figure of the species was obliged at that time to resort to a Victorian specimen. In a later contribution (1953) a specimen, *Ls* 161.8, *Lt* 164.5, from Low Head, Dorset, was briefly described, and the first illustration in Australian literature of the brood pouch was given (1953, fig. 3).

Counts and Dimensions.—A dried specimen from Bellerive Beach, Monmouth, collected by Mr G. Cramp, yields the following counts and dimensions. D.37. P. 11. C. 5. A.? Annuli, total 20 + 48, subdorsal 3.0 + 6.0. Length to origin of pectoral 42, of dorsal 106; to termination of adpressed pectoral 47, of dorsal 137; to vent 117; *Ls* 267.5; *Lt* 272. Head 41, snout 26.5, eye 4.1, interorbital 1.9. Maximum depth 18, maximum width 6.5. The general features of this individual (including location of termination of ridges) agree closely with those of the Victorian example, *Lt* 216, described and illustrated previously.

Variation.—For each species in the 1961 conspectus 9 numerical items are recorded. In one proportion, snout in head, the present specimen exhibits a value, 1.5, falling outside the range previously recorded (1.6-1.8). The recorded number of dorsal rays (inadvertently omitted from the conspectus) has hitherto stood at 38: this specimen has 37.

Coloration.—There are present some elements of pattern not seen in the Victorian specimen. *Head.*—The most striking features are these: (*a*) beginning close to the inferior profile of the snout at a point about two eye-diameters in advance of eye, a slender white line, narrowly margined above and below with black, runs back to orbit at 8 o'clock (left side), leaves hinder orbital border at 4 o'clock, and extends backwards and slightly downwards across operculum near its middle, thereafter continuing briefly to middle of pectoral base [in the Victorian example this element is represented by a white line, not bordered with black, from eye to pectoral base]: (*b*) a darker elongated subrectangular area on hinder half of snout, bounded below by the white line just noted and above by a longitudinal ridge whose posterior portion forms upper boundary of narial basin: (*c*) a dark mesial strip on dorsum of head, originating anteriorly just in advance of level of nostril and becoming continuous posteriorly with the less-sharply defined dark mesial line on upper surface of trunk: (*d*) flanking the last-named element on either side on the head is a lighter region, which is delimited externally by a thin white line apposed to a thin black line, the latter extending caudad on to the trunk, immediately laterad of the superolateral body ridge, being clearly developed at least as far as origin of dorsal. *Trunk.*—(*a*) at about the anterior one-fifth of each scute a thin, even, slightly proconvex bar runs unbroken from inferolateral to mediolateral ridge, where it often ends in a white dot, ringed with black: (*b*) on each scute, between superolateral and mediolateral ridges, are scattered (in parts rather closely crowded) small white black-annulated spots of several sizes, the number per scute ranging from half a dozen anteriorly to a maximum of a couple of dozen near middle of trunk.

Genus SYNGNATUS Linné, 1758

SYNGNATHUS PHILLIPI Lucas, 1891

(Fig. 5)

Syngnathus phillipi Lucas, 1891, *Proc. Roy. Soc. Vict.* (n.s.), iii: 8, 12. Type locality: Port Phillip Heads, Victoria.

Corythoichthys phillipi (Lucas). McCulloch, 1929, *Mem. Aust. Mus.*, v, 1: 87.

Tasmanian status.—The Check List gives Victoria and South Australia only: but, as pointed out in these studies (1939), this species was reported from Western Australia by Waite & Hale (1921: 398), while earlier McCulloch (1911: 26) had noted 4 *Endeavour* specimens from Oyster Bay [Glamorgan], Tasmania. Mr B. C. Mollison has submitted for examination a male *Lt* 97.5, dredged in 9-13 fathoms off Verona, D'Entrecasteaux Channel, Buckingham, on 23rd July 1961.

Proportions.—Following the Handbook (1958: 83), which follows Waite & Hale (1921: 297), the conspectus (1961: 59) gives: snout in head 1.9, head in trunk 2.0, trunk in tail 2.4. By computation from the dimensions of the 4 specimens of the original material, it is found that these single-value entries can be extended to the following ranges: 1.7-2.0, 1.9-2.4, 2.3-2.9. With eye 2.1, snout 6.5, head 13.0, trunk 23.5, tail 61.0, length to dorsal origin 35.0, dorsal base 9.1, *Lt* 97.5, length without caudal 93.8; annuli, total 18 + 44, subdorsal 0.9-5.7, brood caudal I-XVI; D.22, P.10, A.3, C.5 (Waite & Hale, 10), Mr Mollison's specimen conforms in general to the specifications of the conspectus (as broadened above) but yields eye in snout 3.1 (*cf.* 3.4), and extends range of head in trunk numerically downwards to 1.8. Greatest depth of trunk, 3.8, exceeds greatest width, 2.9, and is 1.9 eye (*cf.* Waite & Hale, twice eye), or one-sixth of trunk-length (*cf.* Lucas, in males one-fifth).

Ridges.—These agree with the account given by Waite & Hale, except that the median nuchal ridge in our specimen extends, as reported by Lucas, only to level of insertion of pectoral (*cf.* Waite & Hale, to posterior end of body scute). The discontinuity between this ridge and the median occipital ridge, as noticed by Lucas, obtains. Lucas describes the extension of the supraorbital ridges to form nuchal lateral ridges as being continuous with upper lateral trunk ridges, but in the present specimen there is, as reported by Waite & Hale, a break here, the former, after a very brief turn-down, terminating shortly in advance of, and slightly below level of, origin of latter. The 'marked tetrahedral prominence on the ventral surface of the head, just behind the level of the eyes' noted by Lucas as present in males alone is perhaps merely the inter-ramal triangle of the normal jaw structure adventitiously swung down (as so often happens), but, by coincidence in this case, only in male examples.

Brood pouch.—The location, and extension in terms of rings involved, are recorded by Lucas and by Waite & Hale, but no indication of its character is given. In this specimen, in which it has perhaps not attained its full seasonal development, it is a very simple structure (fig. 5), consisting, on either side, of an integumentary fold devoid of supporting plates. Anteriorly the inner borders are narrowly separated by the interposition of the minute anal (less than 1 mm long); they then diverge rapidly to end of caudal II, where the distance between them is one-third width of ventral surface of tail here: proceeding caudad the folds progressively become narrow to extinction on caudal XVI. A needle can readily be introduced between the folds and the main mass of the tail throughout most of their length, but over the terminal few segments it appeared this could not be done without risk of injury.

Coloration.—Accounts by Lucas and by Waite & Hale call attention to variation in coloration with sex. Comparison of our specimen with the latter, more detailed description yields some noticeable differences: white mottlings on head other than snout few and indeterminate; no actual dots along opercular ridge (careful observation shows, on left side only, three very vaguely defined patches somewhat lighter than immediate neighbourhood); dorsum of trunk with indications of two longitudinal series of lightish areas, but no actual white spots developed; trunk-scutes, between TM and TU, tend, especially in hinder half of trunk, to be lighter at their lateral sutures, but little or no impression is gained of the presence of a full series of bars; about 5 whitish spots, between TM and TL, decreasing in size backwards, on trunk-annuli; ventral ridge on trunk, as noted in both accounts, black: subcaudal scutes behind termination of brood pouch greyish, with one or more narrow darkish areas near each lateral margin; caudal dusky. Waite & Hale observe, 'Brood pouch whitish, streaked with brown': in our example the folds are almost wholly brownish, concolorous with exposed surface of tail between them; laterally, however, along the line of adhesion, there is some darkening, more developed on right than on left fold.

Depth.—See general remarks on depth-records below, under *Solegnathus spinosissimus*.

The 4 type specimens and 3, or 4, examples discussed by Waite & Hale are noted as being dredged; the 4 *Endeavour* specimens from Oyster Bay, [Glamorgan], Tasmanian were probably secured in this way: however, no depth-data are given. The present record, 9-13 fathoms, clearly characterizes *S. phillipi* as a 'deepwater' form in Herald's sense of the term.

Genus SOLEGNATHUS Swainson, 1839

SOLEGNATHUS FASCIATUS (Günther), 1880

(Fig. 6)

Solenognathus fasciatus Günther, 1880, Rept. Voy. *Challenger* Zool., 1, 6: 30, pl. xiv, fig. B. Type locality: Off Twofold Bay, New South Wales.

Solegnathus fasciatus Günther. McCulloch, 1929, *Mem. Aust. Mus.*, V, 1: 94.

Remarks.—Three individuals dredged by Mr B. C. Mollison in 6-10 fathoms in D'Entrecasteaux Channel, off Middleton, Buckingham, on 25th June 1961, provide some interesting data on general proportions, possible sexual dimorphism, eggs and their attachment, prehensive pads, coloration, bathymetrical level.

Counts and dimensions.—Some counts and dimensions of specimens (*a*) female, (*b*) female, (*c*) male, in this order: total annuli 27 + 55, 28 + 56, 25 + 56; subdorsal annuli caudal 2.1—caudal 13.1; 0.3-10 (end of ring),2.1-12 (end); dorsal rays 37, 35, 37; pectoral rays 25, 25, 25; eye 7, 8, 6.5; snout 39, 42, 35; head 63.5, 72.5, 57; interorbital 5, 5, 3.5; trunk 140, 156, 134; tail 150, 159, 152; length to dorsal origin from end of operculum 143, 157, 137.5; dorsal base 37, 38.5, 38.5; depth (in parentheses width) at dorsal termination 8.0 (7.8), 11.0 (9.5), 9.0 (8.5); maximum depth 28, 36, 22.5; *Lt* 353.5, 387.5, 343.

Proportions.—Ranges of proportions given in the conspectus (1961) are transgressed by these specimens in three instances: eye in snout now 4.0-5.6 (*cf.* 4.0-5.0), head in trunk 2.0-2.4 (*cf.* 2.0), trunk in tail 1.0-1.1 (*cf.* 1.0)

Possible sexual dimorphism—In the male maximum depth in length of trunk is 6.0 (females (*a*), (*b*) 5.0, 4.3), or in *Lt* 15.2 (12.6, 10.8): head in trunk 2.4 (2.2, 2.2), or in *Lt* 6.0 (5.6, 5.3): snout in *Lt* 9.8 (9.1, 9.2). It is possible the relatively shallower trunk, shorter head, shorter snout of the male here represents genuine sex differences, the first having been noted as such (Waite, 1895: 222) in specimens identified by him as *S. hardwickii* Gray. Though the male (*c*) is 10.5 mm less in *Lt* than the smaller female (*a*), the width of the ventral surface of its tail immediately behind the vent is more than one-fourth as great again: marked sexual dimorphism in size and form of early tail-scutes has been reported in another species (Waite, 1895: 221); and in *S. dunckeri* Whitley, 1927, the sides of the tail-rings are 'much expanded' in males.

Eggs and their attachment.—Following the Handbook, the conspectus notes simply (as a generic character) 'eggs large, isolated, in open cells on tail.' In dealing with a collection of fishes made in Maroubra Bay by Thomas Whitelegge, Waite (1895) notes Günther's remark 'All the specimens in the British Museum are unfortunately dried, so that the sexes cannot be ascertained; but although some of them must be of the male sex, there is no trace of a pouch or other receptacle for the ova', and proceeds to give (for *S. spinosissimus*) what is apparently the first account of the ova and their mode of attachment in this genus: the observations on this species are accompanied by two figures (unfortunately missing in the copy to which I have access). In dealing later with *Endeavour* material of *S. fasciatus*, McCulloch (1911) observes of the eggs, 'they are very similar to those of *S. spinosissimus* as described by Waite, but are in a less advanced stage of development, and are arranged in about five very irregular rows commencing directly behind the vent and occupying thirteen tail rings'.

In Mr Mollison's specimen the brood annuli are caudal I-XX, extending over 100, or rather more than half length from tip of snout to dorsal origin.

The term 'isolated' as applied to the ova is to be interpreted as meaning they are placed in separate cells: each is attached, however, to its neighbour for more than half its height.

Waite's ovigerous example of *S. spinosissimus* was taken on 4th March, *Endeavour* males of *S. fasciatus* with eggs in a less advanced stage were collected in the latter part of November, while the present specimens were dredged on 25th June.

To follow the disposition of the egg-mass it is necessary to recall the arrangement of the ridges in the relevant area. At level of vent mediolateral trunk ridge (TM) is a trifle nearer to ventral than to dorsal profile. Behind vent it continues caudad on to tail, following much the same course but exhibiting some upward curvature posteriorly, for a dozen annuli, beyond which it then becomes the superolateral ridge of rest of tail (CU), constituting the main dorsal profile. From tip of tail cephalad to level of dorsal termination the mediolateral tail ridge (CM) runs approximately equidistant from dorsal and ventral profiles: from this point it continues forward, without interruption but in a slightly less developed state, to level of vent (beyond which it continues as a line of spinous bosses midway between TM and TL), being in this portion of its course subparallel to TM, its distance below which is from half to two-thirds its distance from ventral profile.

From vent to level of end of dorsal base, the whole ventral surface as far up as TM is wholly covered with a smooth, fairly thick, leathery white integument: behind dorsal termination this integument is less clearly developed, apparently being present, first in a tolerably continuous sheet (thinner than near vent) reaching up to (left), or above (right), level of CM through 7 (left) or 5 (right) post-dorsal annuli, thereafter dropping to ventral profile, and, secondly, in patches that may extend upwards as far as CU. Speaking of this structure in an ovigerous specimen of *S. spinosissimus*, Waite observed, 'It occurred to me this skin might be but the remnants of an egg-case, but as all the male specimens in the Museum, both dry and in spirits, possess it, and as it is scarcely likely that they were all taken during the breeding season, I am led to consider it as part of the animal.' Cells in which the eggs, now detached, have lain vary in shape, ranging from approximate circles or broad ellipses to irregular triangles (rare), quadrilaterals, pentagons, hexagons. Their modal fore-and-aft dimensions (lying in general along, or at a small angle to, anteroposterior axis of tail) is about 3.8, their transverse extent about 2.8. The cell wall, which is a simple fairly thin gelatinous ridge, ranging from virtually colorless to pale yellow, rises (as preserved) to a maximum of about 0.3, with a good deal of the system, however, not more than half this height. The great majority of cells are contiguous, each (except of course those at the periphery of the series) sharing a common wall with (most commonly 5) others: in a few instances only about one-tenth of the total wall-length of a cell may bound that cell only. Ventrally the egg-cells cover the whole of caudal annuli I-XX, in about 3 rows anteriorly, in 2 posteriorly. On left side annulus I carries no cells (though the specialized integument extends up to TM); one cell appears on II; by VII the cellular area extends, with cells in about 2½ rows, to TM; immediately behind dorsal termination it reaches (as its maximum) nearly to dorsal profile, still in about 2½

rows, thereafter dropping with increasing speed, towards ventral profile, reached at XIX. On right side, I and II lack cells: greatest height of cellular region, comprising 2 rows, is reached at X, beyond which its upper border drops, reaching zero at middle of XVIII.

The jar in which the pipefish were preserved contains 62 eggs. This must be the full complement or very close to it. Speaking of two *Endeavour* males with eggs, McCulloch (1911: 27) remarks, 'The most perfect of these bears forty-five eggs, and it would seem that only a very few are missing.' He records that they occupied thirteen tail-rings: it is possible, therefore, that the posterior end of the series was missing. Of the loose ova, largest block, comprising 16, consists of 4 rows of 4 each, in echelon; lengths of rows 14.5, 15, 16.5, 16; width of block, normal to anteroposterior axis, 14.5. The typical egg is pyriform, 6.3 high, with fore-and-aft and transverse diameters each 4.0: attached to its neighbours for about 4, the vertical extent of the unattached portion being slightly greater at the wider (outer?) than at the narrow end. General color yellowish flesh; the more obtuse end with a polar cap (usually sharply delimited) of opaque white that extends from nearly down to point of attachment of contiguous egg to well below that level, modally for a vertical distance of about 1.5 mm (in some eggs this cap is set obliquely to the major axis, in which case it may reach down below equator); at pointed end (and often elsewhere) some scattered areas of opaque white. With superficial moisture dried off 16 ova weighed 0.855 gm. There is nothing in the material as preserved to suggest the eggs are disposed otherwise than in a single layer.

In specimen (*a*) a single ovum 4.0 long was partly projecting through the vent.

Prehensive pads.—The prehensive pads present on the under side of the hinder caudal segments, which appear in dried specimens as low mounds, often collapsed in such a manner as to suggest the occurrence on each annulus of a pair of lateral rounded swellings separated by a median valley, are in the formalin material well elevated, clearly consisting (caudad of the first 3-4, which tend to present separate lateral moities) of a continuous transverse semi-cylindrical roll of white leathery integument up to 2 mm high. They occur in (*a*) on 29, (*b*) 30, (*c*) 29 annuli (thus in all cases there are more tail rings with than without pads; though the longitudinal extent of the padded region of the tail is only about half that of the unpadded).

Coloration.—The original description (Günther, 1880) reads, 'the back of the trunk ornamented with seven narrow blackish cross-bars. Also the praeanal region is blackish'. No sign at all of cross bars can be detected in (*b*): in (*a*) some 4 or 5 darkish areas can just be made out on upper half of trunk (with a darker region covering the 4 immediately post-dorsal annuli): in (*c*) about 7 indistinct bars, of variable width, occur. It was, however, only some considerable time after removal from formalin that any specimen gave any indication of being (apart from the preanal pigmentation) otherwise than unicolorous. In *S. spinosissimus* the trunk also usually has 7 blackish bands: 2 or 3 rings immediately anterior to vent are here bright orange, but this normally changes to blackish shortly after death. It seems evident that coloration, to which Günther attached importance in establishing *S. fasciatus*, is decidedly variable and not of great systematic value. The darkening of the immediately preanal segments, however, is in these examples conspicuous and well-defined against the overall whitish, pale yellowish, or silvery. In (*a*) on right side the last 4 trunk annuli are blackish from ventral profile up to TM; on left side only the last 3 are thus marked: in (*b*) on right the penultimate and antepenultimate rings are dark brown up to TM, and there are 2 small pigmented patches on next ring cephalad; on left only two annuli are marked, the color, which is more intense than on right, ending sharply at TM: in (*c*) on right the last 4 annuli are involved, all being wholly pigmented up to TL, above which, to TM, most of the last 2, but only half of the other 2, are blackish; on left the ultimate trunk ring is wholly dark up to TL, then to TM only in anterior half, penultimate up to TM, antepenultimate very nearly to TM, while some medium pigmentation extends forward on to the posterior one-fifth of the preceding annulus between ventral profile and TL.

Depth.—Herald (1953) has pointed out that pipefishes taken in the Marshall and Marianas Islands in Operation Crossroads in 1946 seem to be clearly divisible into intertidal and deepwater forms, with the demarcation between the two habitats at 10-15 feet. Attention has been called earlier (Scott, 1961) to the general paucity of information on the depth at which our syngnathids occur: in the Handbook, indeed, the only bathymetrical data noted are: 25 fathoms for *Syngnathus mollisoni* Scott, 1955 and an entry 'shelf waters' for the present species and two other members of the genus (*S. spinosissimus* and *S. robustus*).

Solegnathus is essentially a deepwater genus; some depth-records being *S. fasciatus*, type, 120 fathoms, present material 6-10 fathoms; *S. robustus*, 37 fathoms; *S. spinosissimus*, 16 *Endeavour* examples, 15-45 fathoms.

Genus **STIGMATOPORA** Kaup, 1853

STIGMATOPORA ARGUS (Richardson), 1840

(Fig. 7)

Syngnathus argus Richardson, 1840, *Proc. Zool. Soc.* (Lond.), xiii: 29. Type locality: not stated [= Tasmania, *fide* McCulloch (1929: 93).]

Stigmatopora argus (Richardson). McCulloch, 1929, *Mem. Aust. Mus.*, V, 1: 93 (synonymy).

Remarks.—Three specimens, (*a*) *Lt* 53.0, (*b*) *Lt* 76.0, (*c*) *Lt* 144.8, netted in fairly shallow water (entangled in net let down to a maximum depth of about 25 feet) at Verona Sands, Buckingham, in January 1961 by Mr D. Ll. Scott yield some metrical variates lying outside accepted ranges; while (*b*), which carries eggs, and (*c*) provide some information on the brood pouch.

Counts and dimensions.—D. *ca* 54, *ca* 44 (probably imperfect), 63. Annuli 19 + 94, 18 + 101, 19 + 88 (tail imperfect). Subdorsal annuli 10 + 12, 11.2 + 7.0 (probably imperfect), 9.6 + 11.6. Brood annuli —, front of 1 caudal to caudal 14.8 (first 11 with eggs), front of 1st caudal to end of 19th caudal. Length to origin of pectoral 13.8, 21.5, 26.0, of dorsal 23.5, 32.3, 42.8; to termination of adpressed pectoral 14.8, 23.8, 28.5, of dorsal 42.5, 58.8, 74.6; to vent 32.3, 47.0, 58.0. Head 12.5, 19.0, 24.0; snout 7.8, 12.9, 16.1; interorbital 0.6, 1.0, 1.0. Maximum depth (head, trunk) 2.8, 2.5; 2.0, 1.9; 1.6, 1.5. Maximum width (head, trunk) 1.6, 1.4; 2.1, 2.4; 2.9, 4.0.

The number of brood rings in (*b*), 14.8, is less than the 16 given as the lower limit in the conspectus. Total tail rings for (*b*), 101, is the highest recorded: the entry of 94 of (*a*) also exceeds the previous highest total (90). The highest number of preanal subdorsal annuli hitherto recorded is 10: (*b*) has 11.2. Specimen (*c*) has 5 more dorsal rays than the highest count noted in the conspectus—giving for this species the wide recorded range of 43-63 (for a sample of 8, using n in calculation, $\bar{x} = 55.25 \pm 1.50$, range $/\sigma = 4.71$, $V = 7.7$; or, using n—1, range $/\sigma = 4.40$, $V^1 = 8.2$).

Proportions.—All proportions given in the conspectus can be calculated from the measurements above. One, 5.6 for eye in snout (*c*), extends downwards the range (6.0-9.3) in the conspectus.

Ridges.—TM in (*a*) extends to at least caudal XVI; in (*b*) is lost in folds of brood pouch; in (*c*) continues on to caudal XXII (*cf.* conspectus 1961: 61). Median dorsal ridge on snout 'terminates in advance of the eyes' [Waite & Hale (1921: 309)]; in our specimens at level of anterior nostril. Median ventral on snout bifurcates 'below the front margins of the eyes' (Waite & Hale): in (*a*) more than an eye-diameter in advance of eye, in (*b*) at level of anterior nostril, in (*c*) at middle of eye.

Brood pouch.—Readily available information on the ovisac and its contents is more or less limited to the location, longitudinal extent, and color of the pouch folds. Thus Waite & Hale note 'brood annuli 0 (1) + 18-20 (16)'—the entries in parentheses being higher or lower values recorded by other writers; and observe 'brood pouch whitish, or pink when containing young, with longitudinal black streaks': the Handbook (Munro, 1958: 90) gives "Brood pouch (males) subcaudal, eggs protected by skin folds': Whitley & Allan (1958: 56) cite Hedley (1915), 'the males carry the incubating eggs in a pouch on the tail.'

In (*b*) the brood pouch, which is slightly wider than the end of the trunk before it and distinctly wider than the tail immediately behind it, extends over 23 mm, or 14.8 caudal annuli, and carries eggs in the anterior 18 mm, or 11 annuli. Viewed from below the ovigerous region presents, on each fold, an outer series of 26 subspherical bulges (the first and last the smallest), each marking the position of an ovum. Internal to this series is a second shorter series (about equally curtailed at either end), in which the bulges, 17 on left flap, 18 on right, are somewhat less prominent. Since eggs are in a single layer (their vertical diameter being greater than their longitudinal or transverse), the total number is thus 26 + 17 + 18 + 26 = 87. They are pale orange. Viewed as they sit in the pouch, those of the outer row tend to be rectangular or irregularly pentagonal; most of the remainder have 5 or 6 sides. The free border of the flap, which is even in outline (*i.e.*, not undulating in correspondence with the bulges), is in the form of a narrow cord-like, but somewhat depressed, rim or rolled hem. When the specimen was received, the inner margins of the flaps were virtually in contact for about the first half of their length, behind which they were 0.2-0.3 mm apart, disclosing portions of 2 rows of eggs. When the flaps are pinned back, it is seen that there is, internal to general integument of the fold, a thin wrapping wall, having somewhat the appearance of a sheet of cellophane, embracing the dorsal half, or more, of the outer row of ova; with adjoining ova separated by septa of the same mesentery-like tissue. When the fish is viewed from the side, the outer row of egg-chambers is clearly visible, the number of bulges being readily countable: the lower margin descends noticeably below the general profile of the adjoining trunk and tail, while the upper border extends about half way between the level of the ventral profile on either side of the ovigerous region and the actual dorsal profile above it. The brood folds are wholly skinny or membranous, and devoid of special stiffening plates. Lateral aspect of fold (except in the first 3-4 compartments, which are lighter than rest) is darkish brown, darker than flank above it, which is here medium brown with numerous dark punctulations. Below, in its anterior three-quarters, where it embraces the eggs, fold is lighter than on sides, mostly much-punctulated brownish; a narrow inframarginal band (rather better developed on left fold) of orange minutely spotted with dark brown borders the rolled hem of the free margin, which is (especially in its posterior half) distinctly darker than any other part of fold, approaching black; in its posterior 5 mm, where it is closely applied to the inferior surface of the tail, making no appearance on the lateral surface, the fold is chiefly brownish, somewhat ashen internally.

For the anterior 4 of their last 5 mm the inner borders of the folds are virtually in contact; thereafter diverging slightly so that at the point of termination they are separated by about one-sixth of width of lower surface of tail here. Anteriorly they originate as distinct folds immediately behind the vent; but there is some indication of the continuation of an anchoring strip of muscle on either side of vent.

In (*c*) the brood pouch folds, extending over 33 mm or 19 annuli, are loosely open anteriorly, adherent to the tail posteriorly. Though they first project as actual folds beyond the general body level on the first caudal ring, their anterior insertions clearly extend forward to embrace the vent. When pinned back the fold is seen to be connected to the body by a set of transverse fleshy dissepiments, with the formation of a linear series of cells, of which 10 occur in 10 mm. At its outer edge the septum is attached to the thickened free border of the fold; at its inner edge (which tends to be somewhat lower than the outer) to a thin, fairly high, very flexible membranous wall: in the first few members of the set the septa of the two folds

join the common median wall directly opposite each other; further back the points of attachment usually alternate, but occasionally come into coincidence again. The whole of the inside of the ovisac is dull, pale, rather dingy yellow. Externally the folds are dirty whitish, with a well-defined narrow dark stripe along the whole length of the outer border of the fold where it arises from the flank [no such marking in (*b*)]: near the middle of the length a second longitudinal band develops and runs close to, and mostly parallel with, the fold's inner border. No eggs in this individual.

Markings.—The dotted back from which the species derives its name is stated by Waite & Hale to be a fairly constant feature of the female, but to occur also, though more rarely, in the male. In our only female, the small (*a*), *Lt* 53.0, the marking is already represented by a well-defined bar across the dorsum of each annulus from the 1st to about the 25th, the marking progressively fading out over the next half dozen rings: anteriorly the total width of the bars, which are diffuse along their sides, is subequal to their interspaces, while if only the central more deeply pigmented portion be taken into account, the width is from half to one-third as much: posteriorly the bars tend to become somewhat less diffuse and show some indication of breaking up at either extremity into a spot. No spots in (*b*). In (*c*) they are conspicuous: a pair on the dorsum of each trunk annulus and on the tail rings to about end of dorsal fin, beyond which for some 10 annuli they increasingly tend to become bars, one-tenth, or less, as wide as their interspaces. From front of trunk to about origin of dorsal the spots (which are here somewhat smaller, especially the earliest) are joined by a narrow dark line. It would thus seem possible the ontogenetic pathway of these markings on the dorsum is from broad diffuse transverse bands, through narrower bars that are at first without, later with, terminal condensation, to discrete well-rounded spots in pairs. In (*c*) (only) there occurs a noticeable vertical darkening along the anterior and posterior borders of each trunk ring, extending unbroken from TU to TL, wider and otherwise better developed above than below TM.

Genus **PHYLLOPTERYX** Swainson, 1839

PHYLLOPTERYX TAENIOLATUS TAENIOLATUS (Lacépède), 1804

(Fig. 8)

Syngnatus [*sic*] *taeniolatus* Lacépède, 1804, *Ann. Mag. d'Hist. Nat.*, iv: 211, pl. lviii, fig. 3. Type locality: Bass Strait (Baudin).

Syngnathus foliatus Shaw, 1804, Gen. Zool, (Pisc.), V, 2: 456, pl. clxxx.

Phyllopteryx foliatus (Shaw). McCulloch, Mem. *Aust. Mus.*, V, 1: 95. Waite & Hale, 1921, *Rec. S. Aust. Mus.*, I, 4: 313, fig. 61.

Phyllopteryx taeniolatus taeniolatus (Lacépède). Munro, 1958, Handbk Aust. Fish., 22: 92, fig. 641 (in *Fisheries Newsletter*, xvii, 4, Apr. 1958: 20, fig. 641). Scott, 1961, *Pap. Proc. Roy. Soc.* Tasm., 95: 60.

Taxonomy.—It is now known that Shaw's name, under which the leafy sea-dragon has commonly been spoken of in Australian literature for well over half a century, is antedated by Lacépède's. In treating *Phyllopteryx lucasi* Whitley, 1931 as a Western Australian subspecies, I follow, for convenience, the Handbook (Munro, 1958: 92). Whitley & Allan (1958: 48) observe of *P. taeniolatus* 'found in New South Wales, Victoria, Tasmania and South Australia, where it tends to run to two forms: a slender duller-coloured one (*P. elongatus*) [*i.e.*, *Phillopteryx* [*sic*] *elongatus* Castelnau, 1872] and a deep and brightly coloured one (*P. altus*)' [*i.e.*, *P. altus* McCoy, 1882].

Remarks.—With D.35; P. 23; total annuli 18 + ? (imperfect), subdorsal 1.5 + 7; length to origin of pectoral 71, of pectoral 6; length to origin of dorsal from hind margin of operculum 100; dorsal base 37.5; snout 43, eye 7.3, head 63.5, trunk 108, this specimen yields counts and proportions all within the limits recorded in the conspectus. In trunk maximum depth is 32, maximum width 10. No subrostral tag. Bellerive Beach, Monmouth: Mr G. Cramp.

Eggs.—Of a fair number of specimens that have passed through my hands, this is the first with any considerable number of eggs *in situ* (fig. 8), though several have retained traces of their occurrence. Dried orange ova or empty pale yellow shells occur on the first 10 caudal annuli, with some unoccupied cells reaching back on to the 14th. Published records give brood annuli as being from caudal I to XVII, XVIII, XIX: it is possible the egg-mass in this specimen may have extended caudad of XIV, but there is no definite indication that this is so. Eggs, as preserved, are commonly a trifle over 2 mm along major axis, and 2, or rather less, along the minor axis. They are arranged mostly in 4-5 rows on ventral surface of tail, with (except on first 2-3 rings) an additional row extending on to lateral surface on each side; and, are, as here preserved, in a single layer. (The photograph in Waite & Hale (1921, fig. 51) would seem to suggest only a single layer is present there—at any rate in the posterior part of the series). Some fifty ova, or parts of ova, remain in place, and there are more or less obvious indications of the previous presence of about an additional thirty: but the total number may well have exceeded the eighty thus accounted for. Whitley & Allan (1958: 46) state, 'The eggs are of a beautiful ruby colour and one hundred and twenty of them have been counted on a single male'. The unoccupied cells are bounded by low dark walls of integument concolorous with that of the undifferentiated portions of tail: the walled space, which varies in shape from quadrilateral and pentagonal to oval (long axis along, or oblique to, anteroposterior axis of fish) is unfloored, and is a glistening grey, characteristically traversed by the 3-5 low transverse ridges of the ring.

Family GIRELLIDAE

Seven species are given in the Check List: (*a*) *Girella* Gray, 1835, (1) *G. tricuspidata* (Quoy & Gaimard), 1824, (2) *G. cyanea* Macleay, 1881, (3) *G. elevata* Macleay, 1881, (4) *G. zonata* Günther, 1859 [Australia ?], (5) *G. castelnaui* (Thominot),

1883 ['Australia']; (*b*) *Tephraeops* Günther, 1859, (6) *T. tephraeops* (Richardson), 1846; (*c*) *Melambaphes* Günther, 1863, (7) *M. zebra* (Richardson), 1846.

Only one species, (1), is credited in the Check List to Tasmania [this appears in the earliest published State list (Johnston, 1881)]. However, (7) was recorded from our East Coast by Lord (1925) prior to the publication of the Check List (McCulloch, 1929): it has since been reported (Scott, 1935) from George Town, Dorset, and the present communication notes a specimen from Green's Beach, Devon.

Girella elevata, (3), is here added to our fauna, being reported from King Island and from Green's Beach, Devon.

KEY TO GIRELLIDAE RECORDED FROM TASMANIA

1 Operculum scaly. Scales in a longitudinal row between scapula and hypural $>$ 70 (about 80); between lateral line and middle of dorsal base $>$ 10 (about 12), excluding those of scaly fin-sheath. Posterior border of preoperculum sloping downwards and backwards. Flank with about 9 dark bands as broad as, or broader than, their interspaces .... *Melambaphes zebra*

Operculum naked. Scales in a longitudinal row between scapula and hypural $<$ 70 (about 50); between lateral line and middle of dorsal base $<$ 10 (about 8), excluding those of scaly fin-sheath. Posterior border of preoperculum vertical or sloping downwards and forwards. Flank either without dark bands or with about 10-12 dark bands narrower than their interspaces 2

2 Dorsal: spines 14-16; spinous base $\doteq$ 2 soft base, the latter $<$ anal base. Operculum with 1 flat spine. Caudal moderately emarginate, the lobes somewhat pointed. About a dozen narrow dark-grey subvertical bands on each flank in life (usually lost in preservation); individual scales without color-pattern of their own .... *Girella tricuspidata*

Dorsal: spines 13; spinous base $\doteq$ 1½ soft base, the latter $\doteq$ anal base. Operculum with 2 flat spines. Caudal subtruncate, the lobes not pointed. No dark bands on flank, in life most scales with a bluish area near middle and a well-defined bronze posterior border (pattern sometimes traceable in preserved material) .... *Girella elevata*

Genus **GIRELLA** Gray, 1835

GIRELLA ELEVATA Macleay, 1881

Girella elevata Macleay, 1881, *Proc. Linn. Soc. N.S.W.*, V, 3: 408. Type locality: Port Jackson.

Girella elevata. Stead, 1908, Edible Fish. N.S.W.; 51, pl. XX.

Girella elevata Macleay. McCulloch, 1920, *Rec. Aust. Mus.*, XII, 2: 64, pl. XII, fig. 1. McCulloch, 1929, *Mem. Aust. Mus.*, V, 2: 239.

First Tasmanian records.—Two examples—(*a*) *Ls* 295, *Lt* 375 (caudal clumped) or 367 (caudal fully spread), from Grassy, S.E. King Island; (*b*) *Ls* 228, *Lt* 286 (clumped) or 279.5 (spread), from Green's Beach, Devon—add this species to the Tasmanian list.

Specimen (*a*) was received on 12th November 1960 from Mr H. A. Bartlett, Currie, King Island. Mr Bartlett had been aware for some time of its existence in King Island waters—it is known locally as the Butterfish [a name commonly applied on the Tasmanian mainland to *Psilocranium nigricans* (Richardson), 1850, Cheilodactylidae; in South Australia to *Sciaena antarctica* Castelnau, 1872, Sciaendiae; in New South Wales, and elsewhere, to *Scatophagus multifasciatus* Richardson, 1846, Scatophagidae, and, with the epithet 'spotted', to *S. argus* (Linné), 1766]—and had described it to me several months prior to the receipt of the present example. Specimen (*b*) was received at the Queen Victoria Museum, Launceston, from Mr H. L. von See on 15th February 1961: being accompanied by a specimen, *Ls* 178, *Lt* 233, of *Melambaphes zebra* (Richardson), 1846 and a specimen, *Ls* 193, *Lt* 252, of *Scorpis georgianus* Cuvier & Valenciennes, 1832.

Proportions, TLS.—The value for the King Island specimen is in each case given first. Eye 54, 53; interorbital, at anterior border of eye, 108, 96, at posterior border 125, 114; internarial, anterior 55, 59, posterior 67, 72; snout 78, 88; head, hard 247, 246, soft 261, 257. Length to anterior border of vent 559, 575, to posterior 593, 568. Depth at: nostril, anterior 139, 149, posterior 163, 167; eye, anterior border 197, 202, posterior 261, 268; operculum 366, 351; dorsal, origin 383, 390, termination 186, 184; middle of vent 390, 382; anal termination 207, 187; caudal peduncle 156, 154. Pectoral: length to base, front 251, 230, back 269, 243; length of fin, 271, 228; longest (4th, 4th) ray 241, 219. Ventral: length to origin 298, 300; length of fin 229, 211; extending to within 32, 64 of vent; spine 110, 101; rays 1st-5th, 207, 197; 214, 202; 198, 193; 166, 175; 136, 158. First dorsal: length to origin 271, 203; to end of last spine, 610, 618; spines, I-XIII, 27, 31; 53, 48; 64, 75; 80, 83; 83, 93; 102, 96; 104, 92; 100 (imperfect), 92; 87, 112; 86, 110; 81, 119; 86, 114; 92, 128. Second dorsal: length to first ray 627, 636; to termination 856, 836; rays, 1st-14th, 115, 140; 163, 158; 186, 164; 170,160; 164, 145; 159, 145; 159, 145; 146, 132; 139, 132; 125, 125; 115, 105; 108, 94; 98, 88; 85, 66. Anal: length to origin 627, 671, to termination 824, 829: spines, I-III, 42, 44; 85, 68; 90, 96; rays (to base in sheath), 1st-11th and 1st-12th, 149, 167; 193, 197; 186, 208; 200, 193; 186, 189; 176, 184; 156, 171; 132, 145; 119, 145; 108, 123; 92, 107; no ray, 88.

Remarks.—Both specimens agree well in general with the description and illustration given by McCulloch (1920) and with Stead's (1908) photograph. Several points call for comment. (*a*) McCulloch describes, and figures, both nostrils with fimbriate edges (one of the 3 items of key (p. 60) for separation of *G. cyanea* and *G. elevata* is that in former nostrils are 'scarcely fimbriate', in latter 'markedly fimbriate') no fimbriation is obvious in Stead's photograph, though it could be present but unapparent; no noticeable fimbriation occurs in either of our specimens, though a few striae are found near either nostril, particularly in the King Island example. (*b*) The dermal lobe of anterior nostril noted by McCulloch here covers about upper

half of aperture; in clear contrast to blackish surrounding area, being yellowish green (*a*) or pale yellowish (*b*), minutely punctulated with dark brownish. (*c*) McCulloch's plate shows dorsal and anal each ending at its last ray: in (*a*), last dorsal ray is joined to trunk by a slip of membrane, extending up ray (27.1 long) for 11, and presenting a concave free border that ends 9 caudad of base of ray; while in (*b*) a small triangle, approximately 3 long and 3 high, has on its free border two pointed fleshy lobes, of which the anterior, barely 2 long, is twice the length of the first: in anal (*a*) has a slip similar to, but smaller than, that of dorsal, with corresponding dimensions 8, 3.5 (ray 27 long); while in (*b*) the fin at this point has suffered minor damage and the situation remains obscure: there is a hint of the probable presence of these membranes in Stead's photograph, but the point cannot certainly be determined. (*d*) McCulloch observes of dorsal spines that they 'increase rapidly in length to the fifth, after which they increase very slightly to the last' (in contrast, for *G. tricuspidata* he notes 'spines increasing in length to about the eighth and then decreasing again backwards'): as data given above (see *Proportions*) shows, in (*a*) spines increase to 7th (or 8th), decrease to 11th, increase in next 2; while in (*b*) they increase to 6th, beyond which they exhibit several local rises and falls (smoothed in threes, the values suggest a general pattern of rapid increase to 4th, much less rapid over 5th-7th, and an intermediate rate of increase over rest of fin). (*e*) In upper jaw the larger teeth of the single outer series number 8 + 8 in both specimens, all three-pointed, the middle cusp the largest (especially in respect of breadth), but the difference in size between it and lateral cusps becomes less pronounced, particularly in (*a*), in teeth towards outer end of the tricuspid series, which is followed, to the end of premaxilla, by a row of very small subconical teeth; inner teeth minute, crowded, flattened, tricuspid or subconical in a lunule extending anteroposteriorly for 6, 4 mm in middle line and continued backward as two narrow horns with tips 20, 13 apart: in lower jaw a generally similar arrangement, with 11 + 11, or 7 + 7 large or tolerably large central teeth in a single row (McCulloch, 'about fourteen larger teeth in each jaw'). (*f*) Fin counts: D.XIII/14; A.III/11, III/12; P. 19 (McCulloch, 18): V. I/5; C.18, of which about 15 extend to hind border (McCulloch, 15). (*g*) Scales below lateral line between scapula and hypural 52, 51 (McCulloch, 51); about the same number immediately above it: at middle of dorsal 8-9 scales between lateral line and back, not including scales of sheath. (*h*) Our values for the 11 ratios given by McCulloch (his values in parentheses): depth before ventrals 2.5, 2.6 (2.4) in *Ls;* head (total) 3.8, 3.9 (4.0) in *Ls*: last dorsal ray, 3rd dorsal ray, 2nd anal ray, pectoral fin, ventral fin 2.8, 2.0 (2.7); 1.4, 1.6 (1.5); 1.4, 1.3 (1.2); 1.0, 1.1 (0.9); 1.1, 1.2 (1.1) in total head: snout, interorbital 3.3, 3.0 (3); 2.4, 2.8 (3) in total head: eye in preorbital 0.7, 1.1 (eye 'but little broader than preorbital bone': note here, in (*b*), preorbital exceeds eye). (*i*) Upper rays of pectoral with minute scales covering most of rays and membrane; from about 12th ray onward scales extend outward for about half length of ray, then cease on ray and on membrane between successive rays, but persist for half rest of distance to margin on membrane between ray-branches: on both dorsal and on anal scales continue outward beyond the thick sheath, extending halfway, or more, towards margin of fin.

Capture; behaviour.—Mr Bartlett has supplied the following information about the taking of his specimen. It was caught in a channel in a small headland in about 12 feet of water—offshore, where there is a bed of bull kelp, depth increases rapidly to about 30 feet. Several specimens were swimming near the surface, together with young Sweep, *Scorpis georgianus* Cuvier & Valenciennes, 1832, and when pursued they dived for cover. This fish dived under a large boulder on floor of channel, and continued to swim backwards and forwards beneath it till speared. McCulloch gives a interesting account, based on information from Mr McNeill, of the habit of this species of allowing itself to be carried by a wave over the rocks to procure Sea-Cabbage for food, hurrying back with the receding water. Similar movements were observed by Mr Bartlett among King Island examples.

Distribution.—The fact that about forty years after the discovery of this fish (of which Stead (1908) stated that, though it is but little known, he had good reason for believing it to be quite common), McCulloch (1920: 66) should state it 'is known only from the vicinity of Sydney' makes its collection in King Island in 1960 and in northern Tasmania in 1961 of much interest. Whether we have here a genuine instance of discontinuous distribution, or whether the discontinuity is apparent only, being attributable to lack of information, remains for the present undetermined: migratory behaviour may just possibly be a contributory factor in its being overlooked locally for so long.

Family GOBIIDAE

The Check List credits Tasmania with 3 species: (*a*) *Nesogobius* Whitley, 1929, (1) *N. hinsbyi* (McCulloch & Ogilby), 1919; (*b*) *Gobius* Linné, 1758, (2) *G. tasmanicus* Whitley, 1929, (3) *G. tamarensis* Johnston, 1883. Lord (1923) and Lord & Scott (1924) admit the 2 species then described, namely, (1) and (2), and add (4) *G. lateralis* Macleay, 1881. A later survey of local forms (Scott, 1935) retained (1) and (2) (the latter referred to *Arenigobius* Whitley, 1930); suggested (2)—founded (Whitley, 1929) on a short description of a specimen in Johnston MS—is a synonym of (3); advanced reasons for considering (4) may have been entered on the Tasmanian list in error; and described a new genus, (*c*) *Tasmanogobius,* with (5) *T. lordi,* sp. nov. as orthotype

On this basis our list stood therefore at (1), (3), (5): later, when recording a new locality for (3), opportunity was taken to key these 3 forms (1936). Since that date, (6) *Arenigobius bifrenatus* (Kner), 1865 has been reported (under the circumstances noted below) from our waters; and (7) *Stigmatogobius poicilosoma* (Bleeker), 1849, which appears in the Check List as *Mugilogobius galwayi* McCulloch & Waite, 1918, is here added to the local list.

Key to Gobiidae Recorded from Tasmania

(including *Gobius lateralis* Macleay, 1881, probably reported in error)

1 Body without normal scales. Total rays and spines of vertical fins > 32 (≧ 35). Second dorsal: rays > 13 (15-16); base > 2 (≒ 2½) base of dorsal .... *Tasmanogobius lordi*

Body with well-developed normal scales. Total rays and spines of vertical fins < 32 (≦ 28). Second dorsal: rays < 13; base ≦ 2 base of first dorsal 2

2 Caudal greatly produced, its length ≒ head + trunk. Anal and second dorsal each with rays, or combined rays and spines = 11. Distance from origin of first dorsal to termination of second dorsal ≧ distance from tip of snout to origin of second dorsal. A bridle of conspicuous dark bands from eye to pectoral base .... *Gobius bifrenatus*

Caudal not noticeably produced, its length < head + trunk (≦ length to pectoral base). Anal and second dorsal each with rays, or combined rays and spines ≧ 10. Distance from origin of first dorsal to termination of second dorsal < distance from tip of snout to origin of second dorsal. No such dark bridle 3

3 First dorsal with 7 (rarely 6) spines. Scales between axilla and hypural > 40 (≒ 50). Maxilla failing to reach level of anterior border of eye. Interorbital space ridged. *Nesogobius hinsbyi*

First dorsal with 6 (rarely 5) spines. Scales between axilla and hypural < 40 (28-33). Maxilla reaching beyond level of anterior border of eye (to middle or beyond). Interorbital space not ridged; flat or concave 4

4 Scales between axilla and hypural < 30 (≒ 28). Longest dorsal spine = 1st (filamentous). Eye > snout. Interorbital > 4 (≒ 5.5) eye. Second dorsal base ≒ head .... *Rhinogobius lateralis*

Scales between axilla and hypural > 30 (31-33). Longest dorsal spine not 1st (2nd or 5th). Eye < snout. Interorbital < 4 (≒ 2-3) eye. Second dorsal base < (about ¾) head 5

5 Operculum with some large rather indistinct scales: scales of dorsum extending forward to eye. Longest dorsal spine = 2nd: 6th spine ≒ ¾ 5th. Caudal rounded. Usually a blue blotch on first dorsal .... *Stigmatogobius poicilosoma*

Operculum naked: scales of dorsum not extending forward to eye (ceasing near level of pectoral base). Longest dorsal spine = 5th: 6th spine ≒ ½ 5th. Caudal pointed. No blue blotch on first dorsal .... *Arenigobius tamarensis*

Genus **NESOGOBIUS** Whitley, 1929

Nesogobius hinsbyi (McCulloch & Ogilby), 1919

[?] *Gobius pictus* Castelnau, 1872, *Proc. Zool. Soc. Vict.*, 1: 124. Type locality: St. Kilda, Victoria. Preoccupied by *G. pictus Malm*, 1865.

Gobius hinsbyi Johnston, 1904, *Pap. Proc. Roy. Soc. Tasm.*: 10 (Abstract). Type locality: Tasmania. *Nomen nudum.*

(*Gobius*) *hinsbyi* McCulloch & Ogilby, 1919, *Rec. Aust. Mus.*, XII, 10: 215, pl. xxxiii, fig. 1. *Ex* Johnston MS.

Nesogobius hinsbyi McCulloch & Ogilby. Whitley, 1929, *Pap. Proc. Roy. Soc. Tasm.*, 1928: 62, Scott, 1935, *Pap. Proc. Roy. Soc. Tasm.*, 1934: 47.

Localities.—Johnston noted of his material simply that it was Tasmanian: the type is preserved in the Tasmanian Museum, Hobart, and was examined by McCulloch & Ogilby (1919), in the course of preparation of their important paper on Australian gobiids. Their excellent description and figure were based on a specimen 86 long noted as being from 'Wedge Bay, Hobart, Tasmania', where it was collected, in 5-10 fathoms, along with 25 other specimens, 33-62 long, by C. Hedley, in April 1907: this locality-entry should read (see Scott, 1935: 47) 'Wedge Bay, Tasman Peninsula [Pembroke], Tasmania'. McCulloch & Ogilby's material included also Victorian specimens from Queenscliff, Port Phillip.

In the review of the Tasmanian species referred to above (1935: 47) it was recorded that this species is abundant in pools between tide-marks at Burnie [Devon/Wellington] and West Ulverstone [Devon]; and observations were given on colors in life and habits. In January 1935 I found this goby in considerable numbers in The Arm, a long narrow inlet, with a river-like facies, in George Bay, St Helens, Dorset, where it occurred, in from a few inches to a fathom of water, in association with *Stigmatogobius poicilosoma* (Bleeker), 1847.

On 23rd July 1961, Mr B. C. Mollison dredged 11 examples, in association with 4 specimens of *Acanthopegasus lancifer* (Kaup), 1861, in 9-13 fathoms off Verona, D'Entrecasteaux Channel, Buckingham. Apart from one individual of *Ls* 60, *Lt* 71.5, these formed a compact size group of *Ls* 41-46.5, mean 43.40 ± 0.59; *V* 4.5 ± 1.0 (in calculation *n* used). Noticeable features of the coloration are the magnitude and intensity of the (almost black) hypural bar; the clear definition in most examples of the narrow brown bars, and, in some individuals, their continuity across the midventral line; and the conspicuous terminal white spot presented by the collapsed caudal. One specimen of this goby, *Ls* 50, *Lt* 59, was dredged also by Mr Mollison in 6-10 fathoms off Middleton, D'Entrecasteaux Channel, Buckingham, on 25th June 1961: in this the precaudal pigmentation is more diffuse and not nearly so dark.

Genus **ARENIGOBIUS** Whitley, 1930

ARENIGOBIUS BIFRENATUS (Kner), 1865

Gobius bifrenatus Kner, 1865, Reise *Novara* Zool, Fische, ii: 177, pl. VII, fig. 3. Type locality: Sydney, New South Wales.

Gobius bifrenatus Kner. McCulloch, 1929, *Mem. Aust. Mus.* V, 1: 370 (synonymy).

Arenigobius bifrenatus (Kner). Olsen, 1958, *Pap. Proc. Roy. Soc. Tasm.*, 92: 158.

Remarks.—Kner's material was obtained in New South Wales; while the type localities of the synonymic *Gobius bassensis* Castelnau, 1872, *G. caudatus* Castelnau, 1873, *G. filamentosus* Castelnau, 1875 were [Bass Strait], Victoria; Victoria; Adelaide, S. Australia, respectively: and up to the

appearance of the Check List (1929) the species was recorded from these 3 States only. Its addition to the Tasmanian list has been described by Olsen (1958) as follows. 'Specimens were collected in 1950 and identified by Mr I. S. R. Munro, C.S.I.R.O. Division of Fisheries and Oceanography. Reference to their occurrence in George Bay [Dorset/Cornwall] was made earlier (Olsen, 1954). Whitley (1954) listed it as a new record for Tasmania from a specimen caught in West Arm, Tamar River' [Devon]. Olsen notes that, together with *Ophiclinus gracilis* Waite, 1906, it forms part of the diet of juvenile school sharks, *Galeorhinus australis* (Macleay), 1881, in George Bay.

Scamander River specimen.—In March 1961 Mr C. Burrows secured an example of *Arenigobius bifrenatus, Ls* 78, *Lt* 114, in the Scamander River, Cornwall. It was caught, with rod and line, about one mile from the river-mouth: its occurrence at this distance from the sea is not unexpected, the material examined by McCulloch & Ogilby including estuarine specimens from New South Wales, Victoria and South Australia.

The original figure of this species, commonly reproduced in Australian catalogues, is of an imperfect specimen (the type), the whole outer border, and the membrane behind the last spine, of the first dorsal being missing. As noted by McCulloch & Ogilby the perfect fin is rounded, with the 4th and 5th spines longest. In our specimen the spines, which towards the tips become quite filamentous, measure, in sequence caudad, 10.5, 12, 12.5, 13, 13, 7; the longest exceeding (McCulloch & Ogilby, equal to) postorbital portion of head, which is here 10. The chord of the moderately proconvex border of the membrane joining the last spine to the dorsum slopes downward and slightly backward, the interdorsal being reduced to 1 mm.

Fin-counts of our specimen agree with those given by McCulloch & Ogilby: absence of some scales of the caudal peduncle makes an accurate count impracticable, but the number along the lateral line is evidently quite close to the reported 37. Some important dimensions (mm) may be recorded. Head 21, snout 5.1, eye 4.8, interorbital 1.4. Length to origin of: pectoral 22.5, first dorsal 24.5, second dorsal 40, anal 42, caudal (procurrent rays) 74. Base of: first dorsal 14.5, second dorsal 22, anal 21. Length to vent *ca* 41. First and last rays of second dorsal 11.5, 18; of anal 8, 18.5. Longest pectoral ray (11th) 24.

Comparison with values given by McCulloch & Ogilby (quoted below in parentheses), which are based on a single specimen, 142 long, from Sans Souci, Botany Bay, reveal some differences. Head 3.7 (4) in *Ls*. Eye 4.4 (4.6) in head, interorbital 3.4 (2.8) in eye. Snout 4.1 (3.8) in head, caudal peduncle 2.6 (2.1) in head. McCulloch & Ogilby give depth in *Ls* 5.1: in our fish part of the ventral half of the trunk is missing and the greatest depth cannot certainly be ascertained; depth at vent in *Ls* is 5.1.

The essential features of the color pattern are present and well-developed. Caudal has 7 or more narrow dark arcs, one of which is basal: an additional bar, with which it is in contact, to upper border of fin about midway between basal bar and the next normal bar. First dorsal with narrow horizontal marking, made up of a series of oblique subrectangular dark blocks, one to each interradius, set in echelon, but giving, broadly, the effect of a single bar: this occurs along basal one-fourth of fin. Similar bar in second dorsal, on same horizontal level as that on first. No other pronounced marking in either dorsal. Other fins without markings: pelvics very dark. Upper bar of bridle, which is somewhat narrower than first, originates (contrast Kner's figure) below level of middle of hind border of eye; but gives off here a short proconcave spur that approximately parallels orbital border. Proconvex bar from back of eye to near rictus. Upper lip blackish. Dark purplish ypsiliform marking on isthmus with the diverging limbs bordering the branchiostegal membranes. Half a dozen compact squarish or roundish markings above anal base (probably extending further caudad, but scales missing here).

The proximal inflation of the outline of the caudal fin is less pronounced than in the standard figure.

Genus **STIGMATOGOBIUS** Bleeker, 1874

STIMGATOGOBIUS POICILOSOMA (Bleeker) 1849

Gobius poicilosoma Bleeker, 1949, Verh Bat. Gen., 22: 31.

[?] *Gobius olorum*, Sauvage, 1880, *Bull. Soc. Philom.* (7), IV, 43. Type locality: Swan River, Western Australia.

Mugilogobius galwayi McCulloch & Waite, 1918, *Rec. S. Aust. Mus.*, I, 1: 50, pl. iii, fig. 1. Type locality: Patawalunga, near Adelaide, South Australia.

Mugilogobius galwayi McCulloch & Waite. McCulloch & Ogilby, 1919. *Rec. Aust. Mus.*, XII, 10: 224. McCulloch, 1929, *Mem. Aust. Mus.*, V, 1: 376.

Stigmatogobius poicilosoma (Bleeker). Koumans, 1953, Fish. Indo-Aust. Arch., X: 119 (synonymy).

Lizagobius olorum (Sauvage). Whitley 1960 Native Freshw. Fish. Aust.; 125, fig. on p. 125.

Remarks.—The Check List gives, for McCulloch & Waite's species, the type locality (South Australia) only. Whitley (1960) gives the range as Victoria, South and Western Australia, northward to the Hill River. For Australia Koumans (1953: 120) notes Lake Illawana! Port Philipi [sic] near Melbourne! Patawalunga! [type locality], Noarlunga! [South Australia]: among extra-Australian localities he lists the following countries and islands (precise localities not here transcribed): Singapore, Simular, Nias, Java, Bali, Flores, Ambon, New Guinea, India, Philippines—in brackish water and river. Koumans' synonymziation of McCulloch & Waite's species with Bleeker's thus gives it a wide extralimital range.

Tasmanian record.—The species is here added to the Tasmanian list, a number of specimens having been taken by the writer in December 1952 and January 1953 in The Arm, George Bay, Dorset, where it occurred abundantly in brackish water, at a depth of from a few inches to a fathom, in association with *Nesogobius hinsbyi* (McCulloch &

Waite), 1919, *Pseudaphritis urvillii* (Cuvier & Valenciennes), 1831, *Atherina microstoma* Günther, 1861, *Gymnapistes marmorata* (Cuvier & Valenciennes), 1829, *Galaxias attenuatus* (Jenyns), 1842, *Usacaranx nobilis* (Macleay), 1881, *Agonostomus fosteri* (Cuvier & Valenciennes), 1836, *Anguilla australis* Richardson, 1841.

A conflation of notes made in the field yields the following observations on coloration in life. Ground color greenish, or greyish green: many scales margined with fawn or pale brown caused by rather closely set chromatophores. Markings on lateral surface and saddles russet or darkish brown: the most characteristic pattern about 5 not very sharply delimited brownish blotches along midlateral line (in better agreement with McCulloch & Waite's account and figure than with Koumans' diagnosis). Operculum (which has 4-5 rows of scales) darker, except, perhaps, near its posterior border, than rest of side of head. Neither of the markings of the first dorsal described by McCulloch & Waite as blue are invariably so, being at times blackish. Second dorsal greenish, with about 4-5 russet or brownish cross-bars or rows of spots. Caudal pale greenish with about 8, or more, brownish cross-bars. Anal with some brown on the rays; margin blackish. Pectoral membrane almost colorless or greenish; rays more or less yellowish, sometimes with darker spots. Pelvic pale.

Family TETRAODONTIDAE

Three species are credited to Tasmania in the Check List: (*a*) *Tetrodon* Linné, (1) *T. armilla* McCulloch & Waite, 1915; (*b*) *Spheroides* Duméril, 1806, (2) *S. richei* (Freminville), 1813, (3) *S. liosomus* Regan, 1909.

Our early lists included (4) *S. hamiltoni* (Gray & Richardson), 1943: with the identification by Regan of material in the British Museum, including Tasmanian examples, that had been assigned by Günther (1870) to *S. hamiltoni* as a new species, *S. liosomus*, Gray & Richardson's species has been dropped from our list. It is here reinstated.

Observations are made also on species (1) and (2).

KEY TO TETRAODONTIDAE RECORDED FROM TASMANIA

1 Each nostril a simple or bifid tentacle without distinct openings. A large dark band encircling gill-opening and much, or all, of that part of flank that is covered by adpressed pectoral .... *Tetraodon armilla*

Each nostril with 2 distinct openings, usually in a low tube or papilla. No such dark band 2

2 Body without evident spines (but with numerous pores) .... *Spheroides liosomus*

Body with evident spines 3

3 Dorsal 9. Caudal rounded. Back and upper sides with rounded closely-set dark spots; in lateral view > 20 spots visible, their interspaces mostly < (about ½, or less) their diameter .... *Spheroides hamiltoni*

Dorsal 9-10. Caudal emarginate. Back and upper sides with rounded and longitudinally oval well-separated dark spots; in lateral view < 20 spots visible, their interspaces often > their diameter .... *Spheroides richei*

Genus **TETRAODON** Linné, 1758

TETRAODON ARMILLA McCulloch & Waite 1915

Tetraodon armilla McCulloch & Waite 1915, *Trans. Roy. Soc. S. Aust.*, XXXIX: 475, pl. XV. Type locality: Great Australian Bight.

Remarks:—Though the 12 specimens used in drawing up the original account (the figured example, 200 long, being selected as the type) included material from 'Off Flinders Island, Bass Strait, 40 fathoms', this species does not appear in the Tasmanian lists of Lord (1923) and Lord & Scott (1924): it is however, recorded as Tasmanian in the Check List (McCulloch, 1929).

It is essentially a deepwater form, the original specimens obtained during the 1914 trawling cruise of the *Simplon* being secured at 10-40 fathoms; and no Northern Tasmanian fisherman to whom I have mentioned it seem to be acquainted with it.

On 23rd April 1961 I picked up on a beach at East Devonport, Devon, the remains of a fish that appears pretty clearly to be referrable to this species. The specimen, just deposited by the tide and still wet, consisted of the skull and much of the skeleton enclosed in the otherwise wholly empty skin, from which all flesh had been thoroughly and neatly removed, possibly by the action of sea lice.

Genus **SPHEROIDES** Duméril, 1806

SPHEROIDES HAMILTONI (Gray & Richardson), 1843

Tetraodon hamiltoni Gray & Richardson, 1843, Trav. in New Zealand (Dieffenbach), ii: 226. Type locality: Port Jackson.

Tetraodon hamiltonii Richardson. Günther, 1870, Cat. Fish. Brit. Mus., VIII: 280 (*partim*).

Spheroides hamiltoni Gray & Richardson. McCulloch, 1919, *Mem. Aust. Mus.*, V, 1: 430.

Aphanacanthus hamiltoni (Gray & Richardson). Whitley, 1960, Native Freshw. Fish. Aust.: 127, fig. on p. 127.

Status as a Tasmanian species.—The published lists of Johnston (1883, 1891) and Lord (1923), and —*fide* Johnston—the earlier unpublished catalogue of Allport all give (apart from *S. richei*, which does not enter the present discussion) one species, *S. hamiltoni*. In his account of this latter form Günther (1870: 280) stated, *inter alia*, 'The back and abdomen are covered with minute spines; frequently nothing is visible of the spines, except the pores in which they are lodged and then the entire fish is smooth to the touch, some specimens are entirely spineless'. This sounded suggestive of a composite sample; and in 1909 Regan segregated the samples in the British Museum without spines (and having D. 10-11, A. 9, instead of D. 9, A. 7-8)—'Six specimens, 105 to 150 mm. in total length, from Flinders Island and Port Phillip (Degan), Hobart (Allport), and Melbourne (Krefft)'—as *S. liosomus*; and was led to speak of *S. hamiltoni* as belonging to New South Wales and Polynesia. Accordingly, in Lord & Scott (1924: 94) and in the Check List (McCulloch, 1929: 431) *S. hamiltoni* is dropped from the Tasmanian list and replaced by *S. liosomus*.

(Lord & Scott make this alteration in their text, p. 94; but omit to do so in their systematic list, p. 15, which is perhaps based more or less directly on Lord's 1923 list). However, the distribution of *S. hamiltoni* is now known to extend much further south than Regan was in a position to realize. (Whitley (1960: 127) gives the range: 'South Queensland, New South Wales, Victoria, South and south-western Australia and New Zealand'), and there would seem to be no real reason for surprise at its appearance in this State.

Record.—A toadfish, *Ls* 78, *Lt* 96.5, that the writer found washed up in a fresh state, along with 8 examples of *S. richei*, 2 young garfish, *Hemirhamphus melanochir* Valenciennes, 1846, and a small rock whiting, *Neodax semifasciatus* (Cuvier & Valenciennes), 1840, near Beauty Point, Devon, about 9 miles from the mouth of the Tamar River on 21st May 1959 can be referred to this species; which is thus reinstated on our list.

The water at Beauty Point is still highly saline. However, Johnston (1883: 136) noted of '*hamiltoni*', 'entering fresh water at Cataract Bridge on the Tamar' (*i.e.*, some 40 miles from sea), and Whitley (1960: 127) treats of Gray and Richardson's species in his work on Australian freshwater fishes.

Notes on the specimen.—D. 9. A. 8. P. 16, first and last unbranched. C. 8. The spines are best developed on the flanks, ventral surface of head and trunk, occiput, and anterior half of dorsum of trunk, in all which regions they are visible to the naked eye: not, or feebly, developed on caudal peduncle and on dorsum of trunk in advance of dorsal for a distance subequal to postorbital head. *S. liosomus* is described as having fins pale (other than caudal, which is dusky); the standard figure of *S. hamiltoni* [see, e.g., McCulloch (1927, fig. 370*f*)] shows dorsal with a well-defined dark bar across middle: in our specimen the fin has numerous punctulations along the rays and in a large blotch near base, giving it an overall appearance of dirty, somewhat brownish white; it bears also a narrow dark basal band, centrally very compact, but diffuse peripherally. Pectoral: outer surface pale yellowish, with thickly set dark punctulations at antero-superior angle and some chromotophore-edging of rays: inner surface yellowish, deepest basally; right fin with marked, left with moderate, dusking except at inferoposterior angle; on right fin 3 small, on left 5 smaller, spots at proximal ends of rays, these being part of a small system extending on to fin base and thence to trunk. Anal pale yellow, immaculate. Caudal dark brownish, rays somewhat darked than membrane.

Proportions, TLs.—Some proportions of the present specimen are compared in Table V with those of 8 *S. richei* secured at the same time. The smaller values for eye and interorbital in *S. hamiltoni* may perhaps be significant; as may also be the relatively shorter tail.

SPHEROIDES RICHEI (Freminville), 1813

Tetraodon richei Freminville, 1813, Nouv. Bull. Soc. Philom., III: 250, pl. IV, fig. 2.

Remarks.—The circumstances under which the Beauty Point sample of 8 here discussed was secured are noted above in the observations on *S. hamiltoni*. All the fish there mentioned were stranded on a small strip of sand about 10 yards wide, bordered on either side for some considerable distance by rocks. Local residents state toados are constantly being washed up, and during a visit to the district in May 1959 I saw numerous examples floating near, or stranded on, the shore: most showed signs of being in a state of more or less advanced decomposition, but those collected were quite fresh. Except for the one example of *S. hamiltoni* dealt with above, all toadfish seen were the present form; the difference in color pattern is so marked that specimens of the two species can readily be distinguished at a distance of several yards.

Dimensions and proportions.—Table V gives *Ls*, *Lt*, and 7 proportions, in *TLs*, of the 8 specimens, arranged in descending order of *Ls*. The *Ls* range is fairly wide, being 69% of the lowest extreme, or 3.18 σ: with a coefficient of variation of 18.6, the sample seems unlikely to represent a single age-group. No sure indication emerges from the table of correlation between any of the ratios computed and overall size.

Coloration.—The general coloration, as typically developed (specimen (1), *Ls* 125) is as follows. Below midlateral line on flank silvery: under surface rather sharply demarcated, white: above midlateral line brownish, marked with almost black spots and bars (details below). Dorsal: membrane colorless; rays punctulated with brown basally (overall, pale brownish), lighter distally. Anal: wholly white, membrane milky. Caudal: membrane milky; upper and lower rays lightly peppered with brown to near tip, middle rays white basally, all with virtually colorless tips. Pectoral: membrane milky; rays lightly punctulated with pale brownish, which ceases in middle rays at the bifurcation, but continues in others to end, also a narrow dusky bar across bases of rays. Teeth purplish basally.

The dark spots and bars show some variation, here specified for 7 specimens, with the help of a formula: $A + B + C + D + X$, in which A is number of bars (or imperfect bars, constituted by a set of more or less closely approximated large spots) between tip of snout and origin of dorsal; B, under dorsal base; C on main portion of caudal peduncle; D on caudal peduncle at base of caudal rays: while X denotes spots other than those representing elements of imperfect bars.

Specimen (1). 8 + 1 + 1 + 1 + 4-5 on each side. *A* includes 4 on head (1st before nostrils, pale; 2nd between eyes; 3rd just behind eyes; 4th at level of gill-opening). *C* imperfect, constituted by 2 large approximated spots. *X* are large.

(2). 8 + 1 + 1 + 1 + 4 on each side. *C* imperfect.

(3). 8 + 1 + 1 + 1 + 4 (2 dorsal, 2 on left). *A*: 5th short, not reaching sides (and not complemented by lateral spots) 8th imperfect, being one large spot with one larger spot below it on each side. *D*: nearly perfect. *X*: between 7th and 8th bars are 2 dorsal spots (with lateral complement on left only).

TABLE V

Spheroides richei (Freminville), 1913 and *S. hamiltoni* Richardson, 1846. Dimensions of 8 specimens of former, 1 of latter species, from near Beauty Point, Devon, Tasmania. Actual dimensions in millimetres in first two lines: all other dimensions expressed as thousandths of standard length.

Dimension	*S. richei*									*S. hamiltoni*
	A	B	C	D	E	F	G	H	Range : Mean	
Standard length (mm)	125.0	95.0	86.0	81.5	79.5	75.5	74.0	74.0	74.0-125.0 : : 86.3	78
Total length (mm)	155.0	115.0	107.0	103.0	97.5	93.5	94.0	93.0	93.0-144.0 : : 107.2	96.5
Length to vent	688	737	715	742	698	715	682	716	682-742 : : 711.0	815
Head	292	305	320	337	296	317	297	318	292-337 : : 310.3	314
Snout	88	84	110	92	94	113	95	108	84-113 : : 98.0	100
Eye	80	89	102	92	84	93	88	74	74-102 : : 87.8	64
Interorbital	188	184	195	182	170	172	182	182	170-195 : : 182.0	154
Greatest depth	408	432	465	393	333	384	392	446	333-465 : : 406.6	430
Depth of caudal peduncle	90	75	87	90	75	74	78	97	74- 97 : : 83.2	93

(4). 8 + 1 + 2 + 0 + 3 (one dorsal). *A*: 8th is 2 confluent spots, with several lesser lateral spots. *C* is 3 spots, 1 being dorsal. *X*: between 7th and 8th bars are 1 dorsal and 2 lateral spots.

(5) 9 + 1 + 1 + 1 + 0. *A*: 5th, 6th bars are chains of 3 or 4 spots; 9th with large complementary spot on either flank. *C*: 3 spots, 1 being dorsal.

(6) 9 + 1 + 1 + 1 + 2. *A*: 5th is only short bar (a 'long spot'); 9th a bar on either side one larger spot. *C*: 3 spots, 1 being dorsal. *X*: 2 spots high on flank, close to 7th bar.

(7). 9 + 1 + 1 + 1 + 0. *A*: 5th is short bar; 8th is 3 small spots, 1 being dorsal; 9th is a very short dorsal bar, and two lateral spots. *C*: 3 spots, 1 being dorsal.

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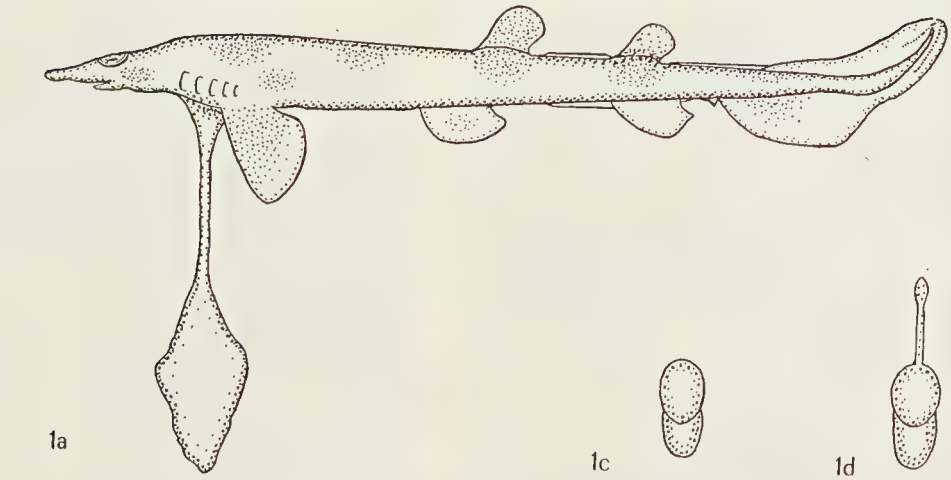
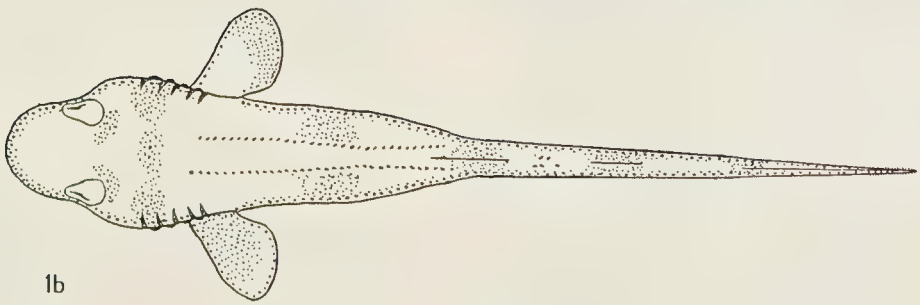
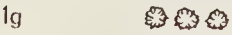






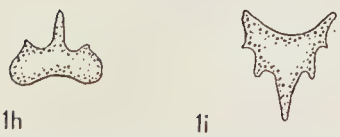
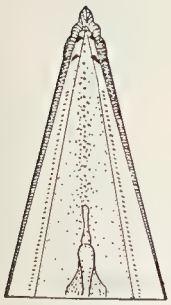


FIG. 1. *Cephaloscyllium isabella* laticeps (Duméril), 1853. *a.-g.*: Embryo, total length 115.5 mm, found, in egg-case, on beach at Falmouth, Cornwall, Tasmania, 1st November 1959. *a.*—Lateral aspect; natural size. *b.*—Dorsal aspect, natural size. *c.*—One of the series of specialized dorsal denticles, viewed from above; × 20. *d.*—Another dorsal denticle, with pedicel, viewed from above; × 20. *e.*—Dorsal denticle, lateral aspect; × 20. *f.*—Three denticles from anterior end of caudal series, viewed from above. × *ca* 10. *g.*—Three denticles from posterior end of caudal series, viewed from above; × *ca* 10. *h-i.*—Adult female, total length 961 mm, found dead on beach, Ulverstone, Devon, Tasmania, 4th August 1933. *h.*—Tooth, lower jaw; enlarged. *i.*—Tooth, upper jaw, enlarged.

FIG. 2. *Muraenichthys brevicceps* Günther, 1876. Lateral view of anterior portion of head of a specimen, total length 439 mm, from Low Head, Dorset, Tasmania, December 1960; × 2.



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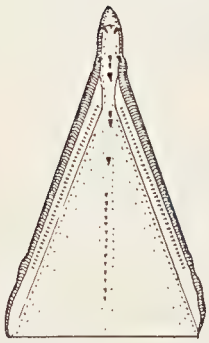

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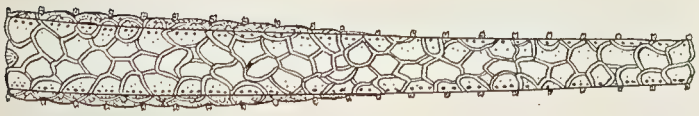

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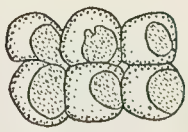

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Fig. 3. *Ophisurus serpens* (Linné), 1758. Specimen, total 1144 mm, from mouth of George River, Dorset/Cornwall, Tasmania, August 1956. *a.*—Lower jaw, internal aspect; natural size. *b.*—Upper jaw, internal aspect, natural size.

Fig. 4. *Leptonotus semistriatus* Kaup, 1856. Dried specimen, total length 272 mm, from Bellerive Beach, Monmouth, Tasmania. *a.*—Head, dorsal aspect; × 1½. *b.*—Head, lateral aspect; × 1½. Pattern of striation not shown.

Fig. 5. *Syngnathus phillipi* Lucas, 1891. Male, total length 97.5 mm, dredged in 9-13 fathoms off Verona, D'Entrecasteaux Channel, Buckingham, Tasmania, 23rd July 1961. Brood pouch; × 2½.

Fig. 6. *Solegnathus fasciatus* (Günther), 1880. Male, total length 343 mm, dredged in 6-10 fathoms off Middleton, D'Entrecasteaux Channel, Buckingham, Tasmania, 25th July 1961. *a.*—Empty brood pouch; natural size. *b.*—Three ova, lateral aspect; × 2. *c.*—Six ova, viewed end-on; × 2.

Fig. 7. *Stigmatopora argus* (Richardson), 1840. Male, total length 76 mm, entangled in net let down to about 25 feet, Verona Sands, Buckingham, Tasmania, January 1961. Ovigerous portion of brood pouch; × 3.

Fig. 8. *Phyllopteryx taeniolatus taeniolatus* (Lacépède), 1804. Dried specimen, combined length of head and trunk 171.5 (tail imperfect), from Bellerive Beach, Monmouth, Tasmania. Ventral aspect of anterior part of tail, showing some dried eggs *in situ* and some empty egg-cells; × 1½.

BREEDING HABITATS OF THE WHITE-FACED STORM PETREL (PELAGODROMA MARINA) IN EASTERN BASS STRAIT

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2. Burrows
3. Plant Communities of Petrel Rookeries
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SUMMARY

The vegetation of eight storm petrel rookeries in the Furneaux Group of Eastern Bass Strait is described in relation to deposition of guano and sea salt. The principal difference between this vegetation and that of the adjacent mutton bird islands is that the dominant *Poa poiformis* forms a dense bluish mat on the petrel islands instead of the more usual yellowish-green tussocks of the mutton bird islands.

Petrel burrows are not necessarily associated with bare soil and many penetrate dense vegetation or are insinuated beneath "false floors" where foliage trampled by Cape Barren geese has become incorporated with soil thrown up by excavating blue penguins.

On three islands Pacific gulls occur with the petrels and their predation and trampling is causing an apparent diminution in the area occupied by petrels. Nowhere are storm petrels associated with short-tailed shearwaters, which burrow on almost all other islands of the group. Cape Barren geese graze in all the petrel rookeries, some of which form transitory nesting sites for silver gulls and crested or caspian terns.

The Furneaux Group petrel vegetation is compared with that of the more severely modified petrel vegetation in the lower latitudes of Victoria and Western Australia.

1. INTRODUCTION

White-faced storm petrels or frigate petrels are locally numerous off the Australian coast, but come ashore only on small, fairly remote islands, so that the type of breding habitat is not generally well known to ornithologists.

During a 2½ year sojourn in Australia visits were made to 17 storm petrel colonies, 8 in the Furneaux Group off N.E. Tasmania, 2 off Victoria and 7 off Western Australia. The present paper places on record the type of terrain utilised in the Tasmanian habitats (latitude 40° S.).

None of the 8 storm petrel islands in the Furneaux Group are more than a few acres in extent and all occur in the relative shelter of Franklin Sound between the 2 major islands of the group, Flinders I. and Cape Barren I.

Their vegetation resembles that of other small islands in the group except for one important feature. This is the life form adopted by the dominant, needle-leaved grass, *Poa poiformis*. The vernacular name of this grass is "Silver Tussock" and on most islands plants do, in fact, form silver tussocks. On all the storm petrel islands, however, but on none of the others visited by the author, they form level swards of soft, bluish-green shoots similar in taxonomic features to the normal form but differing widely in morphological habit.

Mr. J. H. Willis of the National Herbarium, Melbourne, has examined material from a variety of sources and maintains that there are no taxonomic peculiarities. It would be of interest to grow the 2 forms under culture conditions to ascertain whether the storm petrels are as responsible as they seem for inducing what may be termed the "petrel ecotype".

In considerable portions of the Furneaux Group petrel rookeries the *Poa* is replaced by mats of succulent-leaved plants, principally *Tetragonia implexicoma* (New Zealand or bower spinach or green vine) and other members of the Aizoaceae.

Plant lists for the petrel islands will be included in a more comprehensive list for Bass Strait which is in course of preparation by Willis and Gillham.

2. BURROWS

The islands are composed basically of Devonian granite and much humus is incorporated with the derived sands which form the burrowing medium. Where the depth of this is adequate, burrow density is commonly 2-4 per sq. m. and as many as 9 entrances have been seen opening on to an area of this size.

Burrows are short, sometimes as little as 30 cm. long. They may be only 5 cm. diameter at the entrance, broadening into an underground chamber into which short lengths of *Poa* are dragged as nesting material. Larger entrances may be found with several small tunnels leading from them, and it is suspected that these are abandoned blue penguin (*Eudyptula minor*) burrows which have been taken over by petrels. Some of the longer burrows are twisted and a few have more than one entrance.

Where soil is shallow burrows may consist merely of channels roofed by dense carpets of *Tetragonia* or other mat plants. The same type of "burrow" is constructed where soil is adequate but unattainable on account of the overlying vegetation. Association with Cape Barren geese (*Cereopsis novae-hollandiae*) or sheep is helpful in such circumstances, as these animals form tracks through the tall vegetation during the course of their foraging and these tracks allow the petrels access to ground level.

On Apple Orchard Reef off the N. coast of Cape Barren I. an extensive zone of *Stipa teretifolia* (coast barb grass) tussocks 1-1¼ m. high are intersected by goose tracks and the outer leaves of the tussocks are trampled to form uneven platforms. Penguins and a few petrels excavating burrows beside the tracks throw earth onto these platforms and more grass becomes incorporated so that a "false floor" which sags underfoot is formed. Petrels are able to alight on these open strips and burrow beneath them, finding it unnecessary in many instances to penetrate the true ground surface. It is unlikely that the weight of passing geese would inflict damage on the sitting petrel while the stiff *Stipa* leaves retained their springiness.

Furneaux Group petrel burrows, unlike those in the non-organic sandy soils of the Western Australian islands, are not necessarily associated with bare ground, as are those of the short-tailed shearwater (*Puffinus tenuirostris*) on the neighbouring mutton bird islands. The smaller petrels seem more adept at insinuating themselves among plants than are the larger shearwaters and their tunnels may go through more than 15 cm. of "packed" grass shoots before reaching the ground beneath. The birds start excavating in October and keep the burrows open during the plants' principal growing season of spring and early summer. Soil thrown onto the sward in the course of digging is shaken or washed down and the unobstructed grass shoots grow over the entrances and obscure them not long after the burrows are vacated in March.

TABLE 1

Plant species of storm petrel colonies, in order of decreasing abundance

(For explanation of frequency values see text)

Species	Grass Communities	Succulent Communities	All Communities
Poa poiformis	35	23	58
Tetragonia implexicoma	17	35	52
Stipa teretifolia	18	13	31
Rhagodia baccata	4	17	21
Disphyma australe	5	10	15
Apium prostratum	4	10	14
Bulbine semibarbata	4	9	13
Carpobrotus rossii	6	7	13
Lavateria plebeja	1	11	12
Senecio lautus	4	8	12
Muehlenbeckia adpressa	11	—	11
Pelargonium australe	5	—	5
Dichelachne crinita	5	—	5
Sonchus asper	4	1	5
Distichlis distichophylla	—	4	4
Apium (large form)	4	—	4
Aira caryophyllea	3.5	—	3.5
Dichondra repens	3.5	—	3.5
Leucopogon parviflorus	3	—	3
Lolium loliaceum	—	3	3
Senecio glomeratus	3	—	3
Bromus diandrus	—	2	2
Lepidium foliosum	—	2	2
Brachycome diversifolia	2	—	2
Gnaphalium japonicum	2	—	2
G. luteo-album	2	—	2
Scirpus nodosus	1	—	1
Dianella revoluta	1	—	1
Correa alba	1	—	1
Trifolium dubium	1	—	1
Vicia sativa	1	—	1
Olearia phlogopappa	1	—	1
Hypochoeris radicata	1	—	1
Sonchus oleraceus	1	—	1

PLATE 1

PHOTO 1.—Three storm petrel burrows in organic-rich sandy soil on Apple Orchard Reef. The soft-leaved *Poa poiformis* mat, which is characteristic of storm petrel rookeries, is partially overgrown by succulent members of the Aizoaceae (*Tetragonia implexicoma* and *Carpobrotus rossii*).

PHOTO 2.—The stiff-leaved tussock form of *Poa poiformis*, which is characteristic of short-tailed shearwater rookeries, overgrown by succulent, Aizoaceous *Disphyma australe*, Fisher Island Mutton bird rookery.

3. PLANT COMMUNITIES OF PETREL ROOKERIES

Rookery vegetation is of two main types, deep *Poa* swards and thinner mats of succulents or of succulents draped around the bases of *Stipa* tussocks. (See plate 1.)

Eight communities of each type have been analysed and results are shown in the accompanying table, where arbitrary values have been given to the plants as follows:—dominant species (5), abundant (4), frequent (3), occasional (2) and rare (1). The sum of these values is depicted for each type of community and for the two types together, plants being listed in order of decreasing abundance.

The 10 commonest species (7 succulents and 3 non-succulents) occur in both types of community. The remaining 24 species (only 2 of which are at all succulent) are more limited in their distribution.

The glaucous-blue mats of *Poa poiformis* are 20-40 cm. deep and a similar type of growth has been observed only in a colony of diving petrels (*Pelecanoides urinatrix*) on Dannevig I. in the Glennies Group of Victoria. There it is less spectacular, however, as the petrels are mixed with short-tailed shearwaters which are commonly associated with the ordinary tussock form of the grass.

Mat plants exhibit a type of vegetative reproduction seen much less commonly in tussock plants. This takes the form of spherical bunches of radiating shoots produced on the creeping stems and resembling the 20 cm. diameter fruiting heads of the sand dune grass, *Spinifex hirsutus*. Like these they become detached, bowl along the ground and put out adventitious roots to form new plants.

Rhagodia baccata (seaberry saltbush) forms low bushes usually not much more than 30 cm. high in these habitats and offers no obstruction to burrowing petrels (which are found only sparsely under larger shrubs). Most of the other succulents are creepers, often occurring in the more maritime habitats in association with *Stipa* tussocks. *Lavatera plebeja* (Austral hollyhock), the only non-succulent among the 10 most abundant species apart from the 2 grasses, is characteristically associated with areas manured by seabirds.

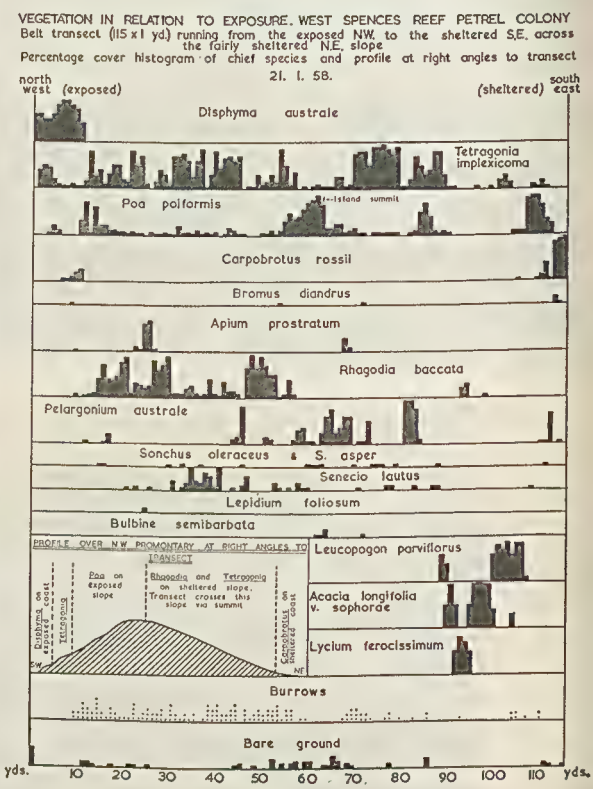
4. PLANT ZONATION IN RELATION TO EXPOSURE

The accompanying figure shows the distribution of the principal plants along a strip passing from W. to E. across the petrel colony of West Spences Reef.

The exposed coast is occupied by *Disphyma australe* (rounded pig-face) the sheltered coast by the less salt-resistant *Carpobrotus rossii* (angular pig-face). The sparsity of petrel burrows among these 2 species (shown at the foot of the diagram) is due to the rocky nature of the substrate. Burrows occur frequently among both where there is sufficient soil.

Tetragonia is dominant more or less throughout the transect with *Rhagodia* co-dominant on windward slopes, although not descending very close to sea level. Throughout this area burrows average 2 per sq. yd., ranging from 0 to 5. The sparsity of burrows in the tussock community which occupies the island summit is again due to rockiness of substrate.

Mixed scrub occurs on sheltered slopes (*Leucopogon praviflorus* (sea currant bush), *Acacia longifolia* v. *sophorae* (coast wattle) and *Lycium ferocissimum* (African boxthorn)). These form a dense thicket about 1½ m. high and few burrows occur beneath them (an average in the transect of 1 per sq. yd.).


VEGETATION IN RELATION TO EXPOSURE. WEST SPENCES REEF PETREL COLONY
Belt transect (115 x 1 yd.) running from the exposed N.W. to the sheltered S.E. across the fairly sheltered N.E. slope
Percentage cover histogram of chief species and profile at right angles to transect
21. I. 58.
north west (exposed)
south east (sheltered)
Disphyma australe
Tetragonia implexicoma
Poa poiformis
Carpobrotus rossii
Bromus diandrus
Apium prostratum
Rhagodia baccata
Pelargonium australe
Sonchus oleraceus & S. asper
Senecio lautus
Lepidium foliosum
Bulbine semibarbata
PROFILE OVER N.W. PROMONTARY AT RIGHT ANGLES TO TRANSECT
Leucopogon parviflorus
Acacia longifolia v. sophorae
Lycium ferocissimum
Burrows
Bare ground
yds.
10 20 30 40 50 60 70 80 90 100 110
yds.

5. PETREL ROOKERY VEGETATION ON INDIVIDUAL ISLANDS

Detailed field reports, species lists and sketch maps of the vegetation have been lodged with the C.S.I.R.O. Wildlife Survey Section Laboratories in Canberra, Hobart and Perth and in the C.S.I.R.O. field research hut on Fisher I. in the Furneaux Group.

a. Isaballa Reef

A *Poa poiformis* mat occupies this rookery with tall *Stipa teretifolia* tussocks encroaching from the windward side and woody lignum (*Muehlenbeckia adpressa*) trailing through it on the leeward side. The large oceanic form of sea celery (*Apium prostratum*?) (see Gillham, 1961) occurs along the W. margin, *Carpobrotus rossii* and *Scirpus nodosus* (sand sedge) are scattered through the sward and *Olearia phlogopappa* (coast daisy bush) occurs in sheltered positions. Few burrows penetrate beneath the bushes and the dense mat of grass had grown across the entrances of most of the burrows in the open by 5th April in 1958.

b. Mid Woody Island

The dominant *Poa poiformis* mat has *Correa alba* (white Correa) bushes scattered through it and *Pelargonium australe* (Austral storks-bill) with *Bulbine semibarbata* (leek lily) and *Rhagodia baccata* occupying protruding rocks. A hummocky *Tetragonia implexicoma* community occurs in the N.E. and centre of the island but contains few burrows. The petrels are concentrated mainly in the S.W. where the *Poa* gives way to a narrow coastal strip of *Tetragonia*.

c. Apple Orchard Reef

This small island is so named because it was once covered with 4 ft. high kangaroo apple (*Solanum aviculare*). This was burned off about 35 years ago and it is not known whether storm petrels ever nested in its cover. No communities of this type have been observed to shelter petrels elsewhere.

Petrel burrows now occur over about ¾ of the island and were probably previously present on that part of the N.E. now occupied by Pacific gulls (see section 6 below). The densest population, averaging 4 burrows per sq. m. and ranging from 1-9 per sq. m., occurs in a fairly pure *Tetragonia* community of the following composition:— *Tetragonia* 80%, *Poa* 16%, *Bulbine* 2%, *Carpobrotus* 2%. As *Rhagodia* comes into the community and the number of subordinate species increases burrows become fewer, and in fairly pure *Poa* swards they number only about 1 per sq. m. In the coastal community of succulent *Carpobrotus* and *Apium prostratum* (normal small form) on the S. they average 3 per sq. m. (range 1-8). This density is maintained among tall *Stipa teretifolia* tussocks in the W. where *Tetragonia* floors the "lanes" between the tussocks. *Apium* is again abundant here with *Disphyma australe* and *Senecio lautus* (variable groundsel). Where the *Stipa* is fairly pure about 4 petrels per sq. m. occur, many of them beneath the "false floors" of goose-trampled shoots mentioned above.

d. West, East and South Spence's Reefs

The flora of these three islands is a mixture of smooth *Poa* sward and low hummocks of coastal succulents. That of the westernmost island has been discussed in relation to exposure and petrels burrow more or less throughout apart from the rocky island summit and the scrub patch of the east.

Burrows are less abundant on the eastern reef but extend beneath the windward margin of the *Leucopogon parviflorus* scrub. *Tetragonia implexicoma* is stimulated and straggles up through the marginal branches (see plate 2, photograph 1) and a number of annuals find living room on the bare, manured soil beneath the shrubs where colonisation by most light-loving perennials is inhibited by shading. European aliens which occur are *Aira caryophyllea* (silver hair grass), *Trifolium dubium* (yellow suckling clover), *Vicia sativa* (vetch) and *Hypochoeris radicata* (cat's ear).

On the southern reef petrels burrow more or less throughout the *Poa* sward and beneath *Stipa* tussocks.

e. Penguin Island

This island consists of two portions separated by a low neck which is occupied by salt marsh. The southern half, like Isaballa Reef, is covered by a dense *Poa poiformis* mat containing *Stipa teretifolia* on the windward side and *Muehlenbeckia adpressa* on the leeward side. *Tetragonia implexcoma* is widespread but depauperate, and very little else is able to compete in the dense growth. Petrels burrow at the rate of about 1 pair per 2 sq. m.

The S.W. part of the obliquely orienated northern portion of the island resembles the southern portion except that part of the western *Stipa* is replaced by *Carpobrotus rossii* and *Disphyma australe*. Petrels are more numerous, burrowing at the rate of about 1 pair per sq. m. In the N.E. this community passes through a transition zone of *Tetragonia* into a *Lepidosperma gladiatum* (sword sedge) community in which petrel burrows are sparse.

f. Rabbit Island.

The *Poa poiformis* mat which occupies most of the island is burrowed almost throughout by petrels where soil is sufficiently deep but burrow density varies widely. The 2 grasses *Dichelachne crinita* and *Aira caryophyllea* and the creeping herb, *Dichondra repens*, are locally frequent with the succulents mentioned above. In the S.W. petrels burrow in *Stipa teretifolia* tussocks thickly draped with *Disphyma australe*. Salt marsh grass (*Distichlis distichophylla*) and *Tetragonia implexicoma* are abundant here. Elsewhere birds burrow in mixed *Poa*/*Tetragonia* swards.

6. ASSOCIATION WITH PACIFIC GULLS

Colonies of Pacific gulls (*Larus pacificus*) have been located in large numbers on only 2 of the 33 islands visited in the Furneaux Group and both of these are storm petrel islands. In both localities gulls have established themselves on areas formerly occupied by petrels, possibly finding the fairly smooth swards of *Poa poiformis* more suitable as roosting sites than the taller tussocks which characterise the mutton bird islands. Their nests, however, are found principally among the adjacent *Stipa teretifolia* tussocks which afford more adequate cover for eggs and young chicks.

PLATE 2

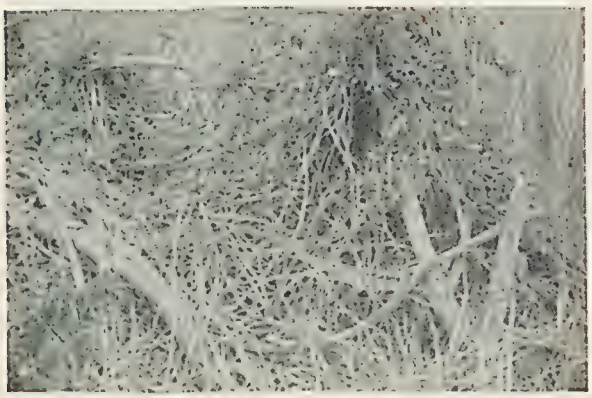


PHOTO 1.—Representatives of the 3 main stages of the degenerative plant succession seen in colonies of burrowing birds—viz: shrubs—tussock grasses—creeping succulents. As bushes of *Acacia longifolia* v. *sophorae* die out the increased light intensity permits growth of *Poa poiformis* and *Helichrysum bracteatum* (left front). Both these and the dead *Acacia* become overrun by succulent *Tetragonia implexicoma*, which, in its turn, degenerates to leave bare soil.

Petrel burrows have disappeared from all the margins of the gull colonies, and it is likely that the nightly landfall might have proved too hazardous a procedure for their survival here. It is also probable that local extermination of the petrels has been hastened by trampling of the burrows as well as predation.

Storm petrels appear to form an important article of food for this species of gull on islands other than the 2 named above. On South Spence's Reef an isolated Pacific gull's nest was located among *Poa, Disphyma* and *Carduus tenuiflorus* (slender thistle). Many of the petrel burrows in the vicinity had been scratched out and the nesting material of dead grass was scattered outside the damaged entrances, together with down and feathers from the victim.

Among the more usual residue of crab claws, mollusc shells, caterpillar skins, &c., around the gull's nest were 10 storm petrel carcases and the legs of many more. There were also the broken shells of about 20 petrel eggs which had apparently been pulled out of the burrows just as the northern greater black-backed gull (*Larus marinus*) removes the progeny of the manx shearwater (*Puffinus puffinus*) from their burrows. More petrel remains were found at three other feeding rocks in the vicinity.

PHOTO 2.—Association of storm petrels and Pacific gulls on Apple Orchard Reef looking N.W. to Strzlecki Peaks on Flinders Island. The white guano crust of the gull roosts is penetrated by succulent, flowering *Bulbine semibarabata*. Storm petrel burrows occur among the *Poa Poiformis* sward (back left) and the *Tetragonia implexicoma* mounds in the foreground, but not in the most gull-fouled zones.

In the two large roosting areas the *Poa* mat becomes trampled and partially coated with a broken crust of dry guano about 2 cm. thick. This forms a "false floor" as in the goose-trampled lanes mentioned above, the guano crust being separated from the peaty soil by a layer of flattened *Poa* leaves 10-12 cm. deep. A scum of green and blue-green algae develops on the guano surface after the gulls vacate the area.

The dead *Poa* gradually disintegrates to give extensive bare patches which are ultimately colonised by succulent plants more guano-resistant than the original *Poa*. The first of these colonists, and one which also penetrates the fouled *Poa* mats, is a russet-leaved form of *Bulbine semibarbata* (leek lily), the species which forms the advancing margin of vegetation encroachng onto vacated parts of the gannet (*Sula serrator*) colony on Cat I. in the E. Furneaux Group.

Plate 2, photo 2, shows a part of the Apple Orchard Reef gull colony with petrel burrows penetrating the *Tetragonia implexicoma* mounds in the foreground. The white area consists of a "false floor" of guano, the tufted plants protruding from it are *Bulbine*, flowering more profusely at the margins than in the centre of the fouled zone. Part of the petrel burrowed *Poa* mat is seen behind.

The composition of this gull roost flora as a whole is as follows:—Guano crust 40%, *Poa poiformis* 45%, *Tetragonia implexicoma* 10%, *Bulbine semibarbata* 5%, *Senecio lautus* v.r.

Two similar areas occur on the northern slopes of Rabbit I., the principal coprophilous species increasing where the *Poa* has succumbed being *Bulbine* and *Lavatera plebeja*. Others are *Rhagodia baccata*, *Carpobrotus rossii*, *Tetragonia implexicoma*, *Pelargonium australe*, *Senecio lautus* and *Sonchus asper*.

7. ASSOCIATION WITH OTHER BIRDS

Short-tailed shearwaters were not found to be breeding on any of the 8 storm petrel islands. This is of particular interest in that they are present on almost all other islands of the group where conditions are suitable for burrowing. The obvious interpretation of this situation is that two species occupying the same ecological niche are unable to live side by side in the same area, but this explanation does not apply in other instances.

Fairy penguins, which burrow in similar soil and vegetation, are present on all the petrel islands discussed; short-tailed shearwaters burrow among diving petrels on the Glennie Group in Victoria and white-faced storm petrels burrow among little shearwaters (*Puffinus assimilis*) and wedge-tailed shearwaters (*P. pacificus*) on islands of S.W. Australia.

All other common birds of the Furneaux Group are to be found on the petrel islands. Most generally present are Cape Barren geese which, if the quantity of their dung can be said to be any reliable indication, spend more of their time grazing on the softer-leaved mats of the petrel colonies than among the coarser tussocks of the mutton bird colonies. Goose nests were found on some of the islands and 15 young geese have been seen on Rabbit I.

Flocks of silver gulls (*Larus novae-hollandiae*) and crested terns (*Sterna bergii*) change their nesting sites from year to year but favour the smaller islands of 1 to several acres, which are those occupied by storm petrels. In December 1958 42 nests of silver gulls were counted on East Spence's Reef and 6 on Penguin I.

Isolated nests of Caspian terns (*Hydroprogne caspia*) have been recorded on Isabella Reef, Spence's Reefs and Penguin I.

8. RELATIONSHIP TO STORM PETREL ROOKERIES IN OTHER STATES

The smaller Bass Strait islands are not subjected to periodic burning, so the petrels burrow in a substrate which possesses a reasonable amount of incorporated organic matter. Other colonies visited by the author are on open sands less retentive of humus, water and plant nutrients and offering a less hospitable plant substrate.

Organic matter has had insufficient time to accumulate to any extent on the man-made island of South Channel Fort in Port Phillip Bay, Victoria (lat. 38° S.). The vegetation of the storm petrel colony here resembles that of the final stage of the "petrel succession" seen in the Furneaux Group, with the perennial succulent creeper, *Tetragonia implexicoma*, the dominant species and the saltbush, *Atriplex cinerea* (barilla) becoming locally dominant.

In the hot dry summers of Western Australia organic matter disintegrates more rapidly than in the cooler moister conditions of the Furneaux Group and the sands which form the burrowing substrate in the storm petrel colonies are not far removed from unmodified dune sands. Evaporation rates in summer are high and the porous aeolianite or consolidated dune sand beneath them retains little water so that guano is not diluted. The resulting flora is a mixture of succulent Aizoaceous herbs and salt bushes, principally *Carpobrotus rossii and Atriplex paludosa.*

In the most southerly colony visited in Western Australia (St. Alouarn I. off Cape Leeuwin, lat. 36° S.) a certain amount of *Poa* tussock persists; in the most northerly (West Wallabi I. in the Northern Abrolhos Group, lat. 28° S.) both this and the Aizoaceous herbs are scarce and the saltbush has yielded pride of place to the even more halophytic *Arthrocnemum* spp. (shrubby samphires) (Gillham, 1961b).

Storm petrels burrow beneath *Arthrocnemum arbuscula* and *Atriplex cinerea* on Mud I., Victoria (lat. 38° S.). Summers here are cooler and moister than in Western Australia but the underlying rock is still aeolianite and the high concentration of the soil solution is maintained by occasional inundation with sea water.

In drier parts of the petrel-burrowed flats on this island practically all perennial vegetation and many of the petrel burrows have been destroyed by erosion resulting from overgrazing by rabbits and disturbance by man. A seasonal growth of *Anagallis arvensis* (scarlet pimpernel) and *Cucumis myriocarpus* (gooseberry cucumber) occupies these rookeries (Gillham & Thomson, 1961).

The Furneaux Group rookeries may thus be regarded as occupying the 3 initial stages in the vegetation series set out diagrammatically in table 2. The vegetation of these initial stages is less seriously modified by the presence of petrels than are the later stages seen in the Victorian and Western Australian petrel colonies, where the effects of guano deposition are intensified by climatic and edaphic factors.

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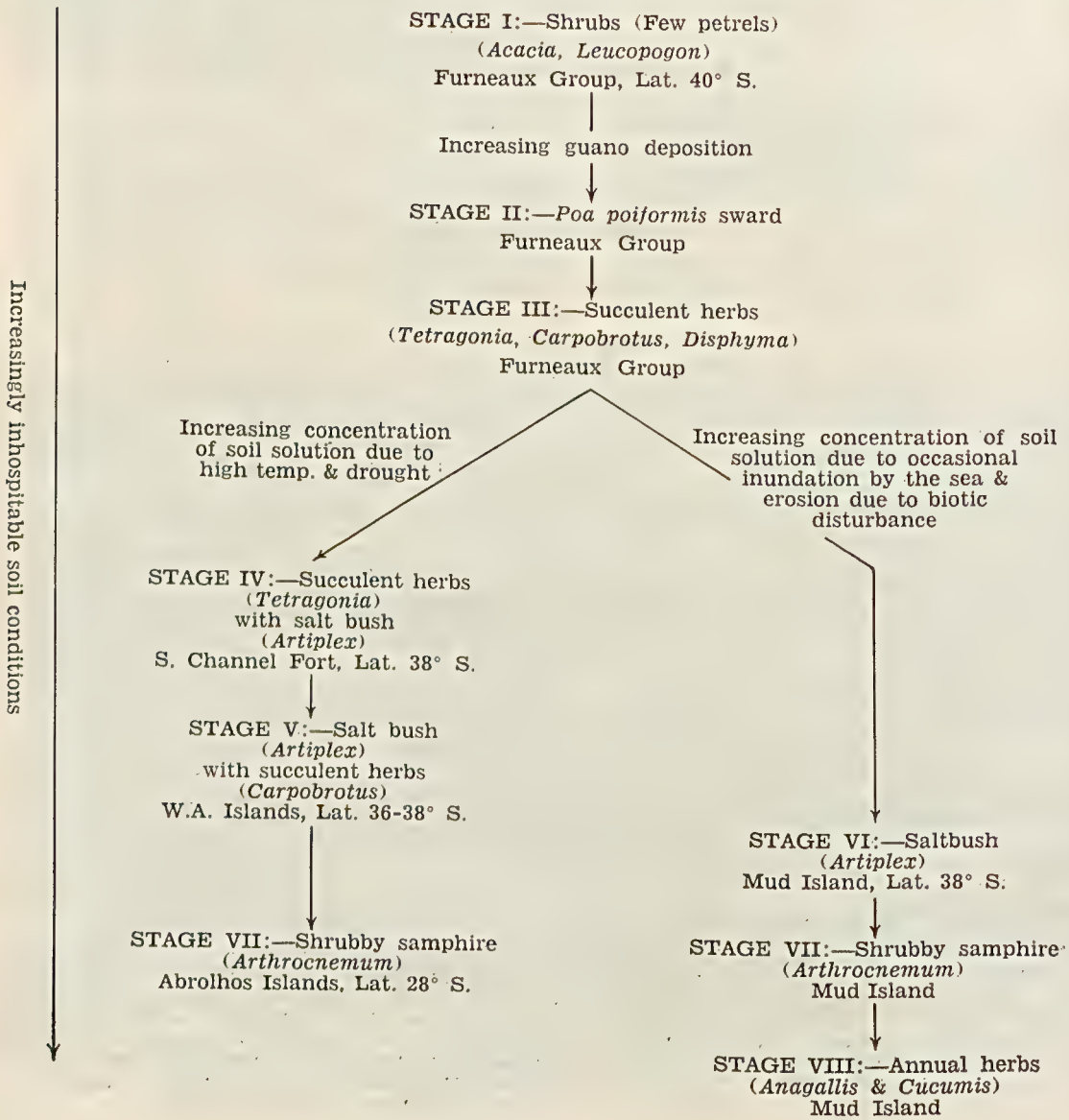
TABLE 2

Plant succession of storm petrel colonies showing effect of increasingly inhospitable soil conditions



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Localities of storm petrel nesting stations in Franklin Sound, Flinders Island.

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CHEMICAL MUTAGENESIS

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I. INTRODUCTION

Although geneticists had often speculated on the possibility of gene mutations arising as a result of reactions between the chromosomes and active chemicals, it was not until the discovery of the mutagenic activity of mustard gas in *Drosophila* by Auerbach & Robson in 1942 that intensive study of this field of work commenced. In the twenty years which have passed, a large amount of work has been done, initially on *Drosophila* and plants, subsequently on *Neurospora,* bacteria and viruses and more recently on mammalian cells. Much of the work on chemical mutagenesis has developed in association with attempts to use the so-called radiomimetic chemicals as effective inhibitors of cell division in malignant tissues. Equally important has been the stimulus provided by the somatic mutation hypothesis of the origin of cancer. Many chemicals have been tested successfully for mutagenic ability because they were already known to be either carcinostatic or carcinogenic in laboratory animals.

Originally the term radiomimetic was used in the sense that the chemical was able to simulate all the end effects of exposure to ionizing radiations. However, the term has more recently been applied to those compounds which satisfy the two criteria of ability to cause chromosome breakage and ability to bring about mutation, it being assumed that carcinostatic and carcinogenic ability are later manifestations of one or the other of these two primary causes. To designate a compound as radiomimetic in this sense in no way implies that its mode of action is essentially the same as that of radiation. Our experimental techniques are designed to detect mutations and chromosome breaks, but these are only the terminal stages of a series of events which may not have involved the same path under all circumstances. We do not know at what stage in the development of biological lesions the pathways from chemical mutagen and ionizing radiation meet. In this respect, it may be noted that some chemical mutagens show an oxygen effect, while others do not.

II. MUTAGENESIS AND CARCINOGENESIS

In so far as the relation between carcinogenesis and mutagenesis is concerned, it has long been realised that a purely chemical consideration of the aetiology of cancer is too narrow and restricted an approach. Although many carcinogens have been shown to be able to act under certain conditions as mutagens, in general there appears to be no quantitive parrallelism between mutagenicity on the one hand and capacity to initiate, or inhibit, tumour growth on the other. There are several examples of chemicals which have mutagenic or chromosome breaking properties but which have not been found to be carcinogenic in laboratory animals. It may be that mutagenic properties are a necessary, but not a sufficient requirement for carcinogenic action. However, most hypotheses of chemical carcinogenesis fail to provide a satisfactory explanation for the fact that some very inert substances have been shown to be carcinogenic. The induction of tumours in rats by the subcutaneous implantation of plastic film can scarcely involve active participation of the implanted material in any chemical processes occurring in the tissues (Alexander & Horning, 1959).

Of the more recently discovered mutagens known to be carcinogenic, the pyrrolizidine alkaloids are of some interest. Esters of complex carboxylic acids with amino alcohols, these alkaloids were first detected in the plant *Senecio,* but have since been found in some of the Leguminosae and the Boraginaceae. They have been implicated as the toxic agents responsible for liver damage in grazing stock (Bull, Dick, Keast & Edgar, 1950) and have also been shown by Schoental & Magee (1957) to be specific liver carcinogens in the rat. Primary cancer of the liver in man is of rare occurrence in the peoples of Western Europe and North America, irrespective of whether they live in Europe, Asia or Africa. By contrast, it is remarkably common in the native populations of certain parts of Africa and South-East Asia (Berman, 1958). It has been suggested that the high frequency of liver cancer is related to the common use in those parts of the world of *Senecio* herbal remedies for a wide variety of ailments.

A number of the alkaloids have been tested for mutagenic properties in *Drosophila* and several have been found to be very active (Clark, 1958, 1960). Heliotrone is the alkaloid which has been most carefully studied so far. It is highly mutagenic when injected into adults or when included in the food. If present in the food at a concentration of about 0.001M, then a twenty-four feeding period causes as much genetic damage as exposure of the flies to more than 1,000 r. of X-irradiation. Prolonged feeding leads to sterility (Brink, 1963). A considerable proportion of recessive lethal mutations induced by heliotrine in *Drosophila* tend to be unstable and may revert back to wild-type. The alkaloid causes breakage in root-tip chromosomes (Anzani, 1961) and in marsupial chromosomes in vivo and in vitro (Clark, unpublished) but no information is available concerning its possible mutagenic activity in higher mammals.

III. CHROMOSOME BREAKAGE AND MUTATION

Because of the relative ease with which cytological observations can be made on cells of actively growing plant root-tips after they have been exposed to solutions of chemicals, much of the screening of chemical mutagens has been based on the ability to produce chromosome breaks. It is certainly true that most physical and chemical mutagenic treatments so far characterised are able to produce chromosome breaks, structural rearrangements and apparent point mutations. On the other hand, a number of compounds are known which are able to produce breaks but yet appear to be unable to bring about point mutations. In some instances, the apparent discrepancy may simply be due to specific sensitivity differences, for while breakage is often scored in plant material, mutations in the more restricted sense are usually scored in *Drosophila*, *Neurospora* or micro-organisms. Cortisone, penicillin and folic acid anatgonists are able to cause chromosome breakage in the *Allium* test (Kihlman, 1960) but are not significantly mutagenic in *Drosophila*.

Many induced mutations are associated with structural rearrangements. They may involve position effects or gene mutations in the proximity of one of the breakage points. The proportion of mutations associated with complex structural changes such as inversions, large deletions and translocations varies according to the dose and nature of the mutagenic treatment. In general, fewer gross re-arrangements are produced by chemical mutagens than by doses of X-rays giving comparable overall mutation rates. In some cases, it has been shown that the scarcity of inter-chromosomal changes is not due to a shortage of breaks. Dominant lethals, which have their basis in chromosome breakage, may actually be relatively more frequent after chemical treatment than after X-irradiation. That there is a qualitative difference in the nature of the breaks induced by chemicals and by radiation seems unlikely, for there is evidence to suggest that breaks induced by chemical treatment may participate with breaks induced by X-rays to give rise to structural changes. Auerbach and Slizynska (see Auerbach, 1960) have reached the conclusion that delayed opening of breaks is the main cause for the shortage of large re-arrangements after chemical treatment. This would also explain the fact that mustard gas, in contrast to X-rays, produces translocations just as readily in late pre-meiotic cells as in post-meiotic cells (Sonbati & Auerbach, 1960).

By the use of the ring chromosome technique, it can be shown in *Drosophila* that a substantial proportion of induced recessive lethal mutations are not associated with breakage events at all. For this reason, while it may be useful in practice to use chromosome breakage as a pointer to possible mutagenic activity, it should not be assumed that breakages and mutations are necessarily related.

IV. MUTAGEN SPECIFICITY

From the standpoint of achieving control over the mutation process, ionizing radiations have the great disadvantage that they are relatively non-specific. Apart from occasional non-random distributions of breaks and the failure of certain alleles to respond to the treatment at all, the usual genetic consequence of exposure to radiation is an overall, non-specific increase in mutation rate. Chemical mutagens, on the other hand, seem to offer the prospect of a greater specificity of action, perhaps even the induction of mutation at only one or two loci at a time.

Specificity of action of chemical mutagens appears in three ways. First of all, there may be a degree of specificity at the taxonomic level. A mutagen may be active in one species but not in another. Manganese chloride and nitrous acid are effective mutagens in micro-organisms but are inactive in *Drosophila*. Differences of this kind could have relatively trivial explanations in terms of accessibility, mode of administration, ease of passage across plasmalemma or nuclear membrane; or they may be the reflection of more subtle differences in the degree to which the mutagen is channelled into ineffective metabolic pathways, in the extent to which the biochemical lesions are subject to repair, or in the suspectibility of the genetic material itself.

A second kind of specificity is reflected by the different sensitivities toward the mutagen shown by various stages in germ cell differentiation. In the rat, triethylene melamine produces more dominant lethals in spermatids than in spermatogonial stages (Bateman, 1960). Mustard gas, on the other hand, produces its maximum effect on late spermatogonia. Differences of this kind may find their explanation along similar lines to those mentioned in connection with taxonomic specificity.

Of greater interest is the question whether, within any one particular cell stage, a mutagen is able to exert a preferential action on particular chromosomes or regions of chromosomes. In some cases, action of this kind could have a simple physical basis. Parts of chromosomes closest to the nuclear membrane during interkinesis might be exposed to higher concentrations of a chemical mutagen diffusing in from the cytoplasm. In plant material, there may be variability in the extent to which different chemicals cause breakage in heterochromatic regions, while in *Drosophila* sex-linked recessive lethal mutations sometimes tend to cluster in certain regions of the genetic map. Fahmy & Fahmy (1957, 1959) have analysed the genetic effects of a large number of carcinostatic and carcinogenic compounds synthesised at the Chester Beatty Research Institute and claim to have established significant differences in the qualitative effects of various mutagens. One of their criteria for specificity of action is the ratio of visible to lethal mutations produced in any given cell stage by the mutagen. Although they refer to the visible mutations as morphogenesis loci, this term does not appear to be very suitable. All genetic loci are morphogenetic. Hence the conclusion of the Fahmys that certain mutagens tend to induce mutations at morphogenesis loci cannot be sustained. However, it is possible that they have discovered that some mutagens tend to produce a high proportion of intragenic changes which may not be fully lethal and hence flies carrying such mutations would survive to be scored subsequently as

visible. Other mutagens, on the contrary, may produce a high proportion of deficiencies, which often have a recessive lethal effect. Differences in the extent to which repair is possible could give rise to change in the ratio of visible to lethal mutations observed in various cell stages.

The Fahmys have also claimed that some of their mutagens act on the gene loci which are stable towards X-irradiation. They report the discovery of more than 200 new loci on the X-chromosome of *Drosophila melanogaster*, new in the sense that spontaneous or radiation-induced mutations had not previously been recorded from those sites. The new loci are called beta loci and they are said to differ from the alpha loci by showing a high degree of radiation resistance as well as specificity of response towards particular chemical mutagens. Auerbach & Woolf (1960) have drawn attention to several unsatisfactory aspects of the work done by the Fahmys. Nevertheless, it should be noted that mutagen stability of the type attributed to the beta loci is well-known in bacteria, bacteriophage and *Neurospora*, and there is no obvious reason why the phenomenon should not be observed in higher organisms.

Some of the best examples of specificity of mutagenic response come from bacteria and viruses. The work of Freese and Benzer (see Freese, 1959) on the fine structure of the rII region in bacteriophage T4 is of particular interest. The rII region in the bacteriophage T4 consists of two cistrons designated A and B. Within each cistron there are many mutational sites, more than 250 in A but only about 48 in B. The following table, based on the data of Benzer and Freese, gives the percentage distribution of mutations induced at four of the sites in the B cistron is a series of experiments. Up to 85% of all the spontaneous mutations took place at site 117, yet none of the hydroxylamine induced mutations involve this site. Although the same number of tests was not carried out for each mutagen, nevertheless the data are sufficient to demonstrate a mutagenic specificity of a very fine order indeed, involving distinct mutational sites within a single cistron or physiological gene.

TABLE I

Percentage distribution of mutant sites induced in the B cistron, rII region of T4 bacteriophage.

Treatment	Site distribution of induced mutants			
	360 %	N24 %	114 %	117 %
Spontaneous	1	5	9	85
Nitrous acid	2	66	3	29
Ethyl methyl sulphonate	10	45	—	45
Hydroxyylamine	25	75	—	—
5: bromouracil	—	82	3	15
5: bromodeoxycytidine	—	60	4	36
Ultra-violet light	4	55	7	34

Of some interest is the fact that certain chemicals may act as anti-mutagens, lowering either the so-called spontaneous rate or the rate induced by a chemical mutagen. Streptomycin is reported by Dubinin (1960) to lower the spontaneous mutation rate in *Drosophila melanogaster*. Guanosine lowers the spontaneous mutation rate in *Escherichia coli* and also reduces the mutagenic activity of caffeine and theophylline.

Reference has already been made to the different responses which various cell stages may give to a particular mutagenic treatment. Effects of this kind are well-known and in *Drosophila* are analysed by the brood fractionation method. Treated males are mated to successive groups of fresh virgin females at regular time intervals. The progeny in each successive brood represent male germ cells which were at progressively younger stages at the time the mutagenic treatment was applied. Identification of particular stages such as spermatids, spermatocytes and spermatogonia can be obtained, but only by controlling the experimental conditions very carefully so as to achieve an even rate of sperm maturation and utilisation. Transition from pre-meiotic to post meiotic stages may be identified by scoring the progeny for induced crossing-over or for induced non-disjunction of the X and Y chromosomes, while clusters of identical cross-overs or of mutants at similar loci serve to identify gonial stages. Recently, Chandley & Bateman (1962) have used tritiated thymidine for the radio-autographic estimation of the rate of sperm maturation in *Drosophila*.

The brood pattern of sensitivity to a particular chemical mutagen may vary according to the species. Thus, triethylene melamine has its maximum effect on late spermatogonial cells in *Drosophila*, but on post-meiotic stages, probably spermatids, in the mouse (Reddi & Auerbach 1961, Bateman 1960). The sensitivity pattern may also depend on the mode of access to the mutagen. Formaldehyde present in the food of larval *Drosophila* exerts its effects mainly on pre-meiotic stages, whereas when injected into adult males its effect is mainly on mature spermatozoa. When fed to adult males, it is only weakly mutagenic. Alderson (1961) has found that the mutagenic action of formaldehyde in the food of the larval stages is dependent on the presence of adenylic acid. The latter alone is not mutagenic. It seems probable that in the case of formaldehyde mutagenesis, there is a real difference between the pathways of mutagenic action in larva and adult. One of these pathways probably involves interference with the incorporation of adenine into the DNA at the time of chromosomes replication.

V. THE MUTATION PROCESS

A correlation between spontaneous mutation and active cell growth has often led to the assumption that cell division is required for mutation. Strauss (1960) goes so far as to say that there can be no mutation without DNA replication. While there is certainly good evidence that some mutations result from errors in gene replication, it is unlikely that this is the only way in which mutation can occur. Some years ago, Novick & Szilard (1951) found that the spontaneous mutation rate to T5 phage resistance in *E. coli* growing in a chemostat was independent of growth rate. It was, however, time dependent. This would suggest that mutation involved some change in an existing gene molecule, rather than an error during replication. However, the interpretation of data from the accumulation of bacterial mutants in a chemostat may be difficult.

Kubitschek (1960) found that if glucose is used to limit growth, the accumulation of caffeine-induced mutants is proportional to the growth rate, thus supporting the error hypothesis. In a later paper (Kubitschek & Bendigkeit, 1961), he finds that if tryptophane is used to limit growth, then both spontaneous and induced mutation rates are found to be independent of growth rate. Since the kinetics of expression of mutation seem to be dependent on the nutrient used to limit growth rate, rather than on the nature of mutagenic treatment, it seems unlikely that in this case the process of mutation can be regarded as an error in template replication. Kubitschek emphasises the distinction to be made between mutation, the induction of which he suggests is independent of the growth rate of the culture, and the physiological expression of the mutation, which may be affected by the nature of the growth-limiting factor employed.

The work of Altenburg & Browning (1961) and of Muller, Carlson & Schalet (1961) argues strongly in favour of mutation involving a change in an already existing gene. The work is based on a study of the proportion of mutations in *Drosophila* found to be fractional, i.e., involving only part of the body of the mutant individual. Multiple markers were used which enable the mosaic or fractional individuals to be scored reliably. According to the Watson-Crick model of DNA, a mutagen which causes an error in gene replication in a diploid embryo should produce a mosaic individual.

More than 50% of spontaneous and chemically induced mutants were found to be fractional, compared with only about 7% of X-ray induced mutants. Most of the spontaneous fractional mutations occur in the spermatid stage, i.e., in post-meiotic chromosomes. If they are delayed effects leading to errors of replication of DNA at the first division of the fertilized egg, one would expect them to be quarter fractionals. In fact, they are mostly one-half effects, so that they can have arisen only as a permanent change in one of the strands of an already existing double strand DNA molecule of the post-meiotic chromosome.

How the spontaneous and chemically induced fractionals are produced is at the moment only a matter for speculation. It seems unlikely that a chemical mutagen would bring about a direct chemical change in a base, the latter remaining attached all the while to the DNA strand. If, on the other hand, the chemical reaction involves removal of the base, it would tend to be restituted by the complementary base in the other strand, thus giving no genetic change, unless double breakage had caused rotational substitution. But in that case, the mutation would no longer be fractional. Substitution of base analogues might produce mosaic fractional mutants, but then it would be necessary to assume that the chemical mutagen acts by bringing about a change in the pool of purine or pyrimidine bases, an altered analogue subsequently being incorporated during replication. In any event, this explanation would not apply to the half-fractional mutations induced in post-meiotic chromosomes in *Drosophila* germ cells.

There is good evidence from bacterial and phage genetics that base analogues may induce mutations and, in some cases, incorporation of the analogue into the DNA has been demonstrated (Rudner, 1961). It is generally assumed that the mutagenic action is directly related to the incorporation of the base analogue. On the other hand, it is also known that in the T phages, for example thymine can be replaced almost completely by bromouracil without preventing the production of viable phage by lethal mutation. Transforming principles may still retain their activity after being heavily substituted with bromouracil. It is difficult to avoid the conclusion that the incorporation of a base analogue is not the only factor involved in the mutagenic activity shown by such compounds.

The mode of action of a chemical mutagen in higher organisms becomes even more difficult to visualise in the light of recent cytological evidence in favour of a multi-stranded structure of the chromosome. It is customary to regard the Watson-Crick model of DNA as being also a reasonable model of the structure of the chromosome as a whole, notwithstanding the obvious fact that these are two structures of quite different orders of magnitude. Since there are good reasons for believing that in some cases a single chromatid may contain at least sixty-four strands of DNA double helices (Steffenson, 1961), it is not easy to see how chemical mutagens produce any genetic effects at all.

VI. CONCLUSION

In conclusion, what generalisations can be made about chemical mutagens on the basis of the present state of knowledge? Clearly, they may be as potent as ionizing radiations in their effectiveness in bringing about genetic change. Sensitivity differences are striking. There are clear indications of specificity of action, so that an altered spectrum of genetic effects may be obtained by the use of a variety of mutagens. Many of the induced mutations are fractional and can give rise to delayed manifestation or the production of mosaic individuals.

On the other hand, no generalisations can be made about the mode of action of the mutagenic and chromosome breaking chemicals. Dozens of different substances have been screened and found to be active. A list of some of them would include alkylating agents, nitrogen mustards, formaldehyde, phenol, glycol, ascorbic acid, acridines, basic dyes, certain sugars, quinolines, menthol, insecticides, urethane, barbiturates, organic arsenicals, peroxides, cyanides, the salts of heavy metals, chelating agents, sulphides, urea, alkaloids, various natural oils such as lavender and eucalyptol, penicillin, salicylates and caffeine. Where is the common factor? Most cells will show some kind of cytological or genetic response to X-irradiation and it would be reasonable to assume that the biochemical events following the absorbtion of radiant energy are in most cases essentially the same. No such simplifying assumption can be made for the chemical mutagens.

One final point to be mentioned concerns the possibility that some of the chemicals in common use in food processing or therapeutics may have mutagenic properties in man. Much time is devoted to the discussion of the genetic significance

of relatively small increases in the levels of background radiation to which human populations are exposed, yet little interest is shown in the possibility that genetic damage may result from mass exposure to chemical mutagens. Caffeine is a powerful mutagen in bacteria and fungi. It is a weak mutagen in *Drosophila*. The only published experiment describing an attempt to assess its mutagenicity in the mouse gave a negative result. What conclusions can be drawn as to the possible genetic consequences of the daily cups of tea and coffee? It is to be hoped that the current interest in the ability of drugs, such as thalidomide, to produce developmental malformations or phenocopies may ultimately stimulate interest in the desirability of adequate genetic screening of new therapeutic agents before they are released for general use.

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FREDERICK STRANGE—ARTIST—c.1807-1873

By

Clifford Craig and Isabella Mead
Launceston.

(With 10 plates)

The work of Frederick Strange, although well-known during his lifetime to the various small communities in which he lived, has through the years been almost forgotten.

Ten years ago, probably no more than ten of his works were known. Scarcely anyone could have told you anything of the man himself. Now, it is realized that his work was much more prolific than was at once thought. He was a painstaking artist revelling in a wealth of detail that enables those who are interested in the past to reconstruct it with authenticity and clarity. He has recorded buildings which, but for him, would be unknown and unimagined by people to-day. To this topographical artist history owes a great debt. As well as leaving a unique record of the Launceston of the middle of the last century, Frederick Strange has left us paintings in which we find good drawing and perspective together with delicate colouring and interesting composition. These paintings and drawings have been one of the most interesting 're-discoveries' in this decade.

Frederick Strange was born in Nottingham, England, in 1807. Of his parents and early life in England nothing is known. His subsequent record, however, suggests that probably, after doing an apprenticeship as a house painter, he became involved with bad companions. Economic conditions in England were such, at this time, that many Fagin-like gangs existed and were accepted as part of the life of the country. Perhaps Frederick Strange, portrait painter and house painter, was forced to join one of these.

At the Quarter Sessions, Colchester, Essex, on the 22nd June 1837, he was tried for stealing a watch. He was sentenced to life imprisonment. His gaol report says that his character and connection was bad. His hulk report was good, however, as was the surgeon's report on his health.

Frederick Strange was transported in the convict ship "Neptune" which sailed from Sheerness on the 7th October 1837 and arrived at Hobart Town on the 18th January 1838. The "Neptune" carried 350 male convicts, two of whom died during the voyage out. The Hobart Town Courier has this report of her arrival.

> "Jan. 18—the ship Neptune, 647 tons, Ferris, from Sheerness 7th October, with Government stores and 348 male convicts—passengers, Dr. J. Steret, Capt. Mainwaring, Mrs. Mainwaring, 2 children and servant, Ensign Paget, 2 serjeants, and 27 soldiers of the 51st regiment, 8 women and 6 children."

Frederick Strange does not appear to have been assigned on his arrival but to have been employed as a Government messenger. Like many convicts it appears that he found it difficult to keep out of trouble. His personal appearance probably did not help in this. He was a most remarkable looking man. He had dark brown hair, red whiskers, light brown eyebrows, dark blue eyes. He had a high forehead and a pale complexion. He was just over 5½ feet in height.

In 1841 Strange was given a third-class pass order and found his way to Launceston. Here he evidently set up as a painter, for Henty Button in "Flotsam and Jetsam" says (page 115) that in 1846 or 1847 Mr. and Mrs. Waddell had their portraits painted by Frederick Strange. At the same time Mrs. Waddell had Mr. Strange paint also a portrait of their nephew Henry Button. The portraits of Mr. and Mrs. J. S. Waddell are now hanging in the schoolroom of Milton Hall, Frederick Street, Launceston, but the whereabouts of the Henry Button portrait is unknown.

Henry Button relates also, that in 1848 after his association with John Glover (Henry Button married John Glover's grand-daughter) he had a strong desire to draw and went to Mr. Strange for lessons. Strange was evidently also a drawing master and Button made very good progress. (Flotsam and Jetsam page 125). Mr. Button does not say where he went for his lessons, but it was probably in Mr. Strange's house in York Street. Here, in 1848, according to the census return of that year, Frederick Strange was living alone in a brick house owned by Thomas Scott. He had a ticket-of-leave and was a "dissenter" in religion (Census 1848). This brick cottage was probably one in York Street above Tamar Street where property belonging to Thomas Scott joined that belonging to W. E. Lawrence (Lands and Surveys Dept.).

Soon after this, it appears that Strange moved back to Hobart and Henry Allport says that there he worked for a man named Graves who had been a varnish maker in the Old Country and who then kept a painter's shop at the corner of Barrack and Macquarie Streets. Graves, says Mr. Allport, later moved to the corner of Melville and Elizabeth Streets and Strange continued to work for him there.

The oil painting of Battery Point, painted by Strange in 1848, probably during his stay in Hobart, is now in the Queen Victoria Museum and Art Gallery, Launceston. On the 4th December 1848 he received a conditional pardon. (Hobart Town Gazette 4th December 1848 page 908.)

He does not seem to have stayed long in Hobart—in fact his sojourn there does not appear to have been noticed by his Launceston friends, for by 1851 he is exhibiting at the Launceston Art Exhibition. The "Examiner" in reviewing the Exhibition says " . . . but we must not omit the name of another exhibitor to the Exhibition, Mr. Strange. This artist has resided in Launceston for several years and his paintings will be at once recognisable from their local character, many of the landscapes have been taken from the immediate neighbourhood whilst some are views of the town itself . . ." (The Launceston Examiner 5 March 1851).

In December 1855 Frederick Strange announced that he had removed to Paterson Street opposite Stewart's coach building establishment where lessons would be given in landscape drawing, and portraits taken in oil or by daguerrotype. (The Launceston Examiner 11 January 1855.)

In 1858 Strange painted the delightful watercolour of Brisbane Street, Launceston, which hangs in the Queen Victoria Museum and Art Gallery. This was reproduced by A. D. Baker in "Life & Times of Sir Richard Dry," 1951 (opposite page 33); and in the 1958 Calendar of the National Bank of Australasia. Another watercolour of Launceston from near the Cataract Gorge was painted about the same time.

An advertisement in The Launceston Examiner 15th January 1859 reads—". . . to be raffled for—an oil painting of Launceston, by Strange, 5 x 3½ feet—20 members £1-15-0 each. To be seen at the studio of the artist, Cameron Street, adjoining Allen's Land Mart"—(The Launceston Examiner 15th January 1859). Evidently, between 1855 and 1858 Strange moved his rooms from Paterson Street to Cameron Street, Launceston.

The Mitchell Library has in its collection a picture of an old water-power sawmill near Launceston, Tasmania, drawn by F. Strange about 1860, copied by A. Collins 1928. It has also an oil painting of Launceston, 1860. The lettering on the back of this says 'painted by Strange, artist, Launceston 1860'.

Mr. Henry Allport says that there was published by R. V. Hood in the 1860s a very good lithograph of Hobarton from Knocklofty and that this drawing was done by Strange. When this drawing was done is not known.

In recent times important discoveries of Strange paintings of Launceston have been made by Mr. Clive Turnbull of Melbourne and Dr. Geraldine Archer of Launceston.

In 1862 the premises that Strange occupied in Cameron Street, opposite the Commercial Bank (the present Equitable Building Society) were taken over by Mr. C. A. H. Williamson who was prepared to execute every description of photographic likenesses at greatly reduced prices. Probably Strange was unable, or, being an artist, did not want, to cope with the advent of photography, for daguerreotype portraits had become much more fashionable than painted portraits. He seems at this time to have turned to trade, for in the Directory of Tasmania 1867 he is classified as "Grocer" Charles Street, Launceston. Here he died on the 31 March 1873. The funeral notice said—"Friends are invited to attend the funeral of the late Mr. Frederick Strange which will leave his late residence, Charles Street, on Tuesday (this day) at 3 o'clock. Hills, Undertaker, Brisbane Street," (Examiner, 1 April 1873). His death certificate says he was 64 years of age, that he died of rheumatic fever and describes him as an artist. Being a dissenter he was probably buried in the Charles Street General Cemetery, although there is no record of this and the cemetery is now a reserve.

STRANGE'S PAINTINGS

Strange did not sign his work. Occasionally "Strange" is to be found roughly printed on the stretcher of a painting. The attributions are made as a rule by consideration of the style, but of course information handed down by word of mouth has been of great value.

Tasmanian Museum, Hobart

1. In "Early Art In Tasmania" Henry Allport says "Many years ago the picture in our Art Gallery depicting the New Town Road near the Harvest Home Tavern was purchased as th work of John Glover, but the late R. L. Hood always asserted that it was painted by Strange. As Hood did nearly all of Strange's framing and stretcher-making, and knew him and his work intimately, it seems more than probable that he was correct." This is an oil painting. 50½ x 41 inches.
2. Hobart Town from Mount Knocklofty. Oil on canvas. 50½ x 41 inches.

Queen Victoria Museum, Launceston.

3. Launceston from Cataract Hill. Watercolour. 55¾ x 33¾ inches.
4. Brisbane Street, Launceston. 1858. Watercolour. 19 x 10⅛ inches.
5. The Gorge, Launceston. Watercolour. 14 x 8 inches.
6. Launceston from the Westbury Road. 1859. Oil. 58¾ x 34¼ inches.
7. Hobart Town, showing St. George's Church and the Mill. 1848. Oil. 36 x 24¼ inches.

Dr. Geraldine Archer, Launceston

8. Launceston from Windmill Hill. Watercolour. 20 x 10⅞ inches.
9. Stephenson's Bend, Tamar River, Launceston. Watercolour. 19⅝ x 11¾ inches.

Milton Hall, Launceston

Both these paintings are in oil.

10. Mr. J. S. Waddell. c.1846. 27 x 35 inches.
11. Mrs. J. S. Waddell. c. 1846. 27 x 35 inches.

Mitchell Library, Sydney.

12. Saw-mill, Launceston. 1860. This is a copy by A. Collins 1928. 15⅞ x 9⅞ inches.
13. An oil painting of Launceston. 1860. On the back of this is "Painted by Strange, artist, Launceston 1860". 35½ x 23¾ inches.

Mr. Clive Turnbull, Melbourne.

Mr. Turnbull purchased this set some years ago from an antiquarian bookseller in Melbourne. They were in an old leather cover. It is obvious that Strange had prepared this numbered series with the idea of producing a book of engravings. Many of the buildings shown have now been demolished. The inscriptions given are in handwriting on the mount beneath or on each picture. All are watercolours.

14. Frontispiece. There is no inscription other than "Frontispiece". It is a view of Launceston from Hill Street. 11.9/16 x 7.4/16 inches.

15. "City of Hobart. / General view looking south-east. / Plate No. (1)." 9.14/16 x 6 inches.

16. "Stevenson's Bend. / Banks of the Tamar, four miles below / the Town. Plate No. 2." 9.15/16 x 5.13/16 inches.

17. "View of Launceston / from over the River Bar. / Plate No. 3." 10.1/16 x 6.14/16 inches.

18. "Mouth of the South Esk River, / with Cataract Mill & Punt. / Plate No. (4)." 9.15/16 x 5.14/16 inches.

19. "Plate No. 5." This is a view of the wharf from across the river. 11½ x 7.2/16 inches.

20. "View of the town & river Tamar / from Windmill Hill. Plate No. 6." Immediately beneath the picture are "York Street", "Brisbane Street", "Patterson Street", "Cameron Street". 10 x 6.4/16 inches.

21. "Banks of the River North Esk / from the Bridge. / Plate No. 7." 10 x 5.10/16 inches.

22. "Brisbane Street / looking west. Plate No. 8." Immediately beneath the picture commencing from the western end are "J. Crooks", "E. Dease", "J. Robertson", "Tamar Ins. Comy.", "McEeacharn", "Cornwall Ins. Compy.", "J. Hudson" "T. Sadler", "A. Duthie", "D. Murray", "H. Bennett". 10.14/16 x 5.13/16 inches.
The section shown is the northern side between Charles and St. John Streets.

23. This shows six separate buildings "1. (Trinity Church corner of George & Cameron Streets)". Beneath this is "2. (Wesleyan Chapel, Patterson Street.))', "3. Post Office, George Street." Beneath this is "4. Baptist Church, York Street." "5. Union Bank, George Street." Beneath this is "6. Roman Catholic Church, Margaret Street." Beneath the whole is "(Public Buildings) Plate No. 9". About 3¾ x 2½ inches each.

24. This shows three separate buildings. Beneath the group is "(Jews Synagogue, St. John Street)," "(St. Andrews Scotch National / Church.)" "Court House, Patterson Street) / Plate No. 10." About 3¾ x 2½ inches each.

25. "St. John's Episcopal Church St. John's Square Plate No. 11." 9.14/16 v 6.11.16 inches.

26. "St. John's Congregational Church / St. John's square. Plate No. 12." 9.15/16 x 6.5/16 inches.

27. "Upper St. John Street, looking North. / view taken from opposite the residence / of H. Dowling Esq. / Plate No. 13." 9.2/16 x 4.5/16 inches.

28. "Cameron Street, looking towards the / Botanical Gardens. / Plate No. 14." Immediately beneath the picture are "Police Court)" "(Bank of Tasmania)". 9.3/16 x 6 inches.

29. "Bank of Tasmania & Residence of F. Evans Esqr. / Cameron Street. / Plate No. 15." 7.2/16 x 4.5/16 inches

30. "Launceston Club Hotel / Brisbane Street. / Plate No. 16." 7.14/16 x 5.4/16 inches.

31. "Third Basin on the River Esk." 8.12/16 x x 5.8/16 inches.
"Ben Nevis" from Greenhill. / Plate No. (18)." 5.8/16 inches.
This is not a watercolour by Strange. It is a coloured lithograph after a drawing by Miss Elizabeth Hudspeth. It is No. 18 in the Series but Strange had not specially marked it as not being by himself. 8 x 5.14/16 inches.

32. "Messrs. Grub & Tyson's Saw Mill / Piper's River. / Plate No. 19." 11.3/16 x 6.10/16 inches.

Launceston Club

33. Launceston from the Westbury Road. Water colour. 11¾ x 6¾ inches.

34, 35. There are two watercolours privately owned in Hobart but no details are available.

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(No. 8) LAUNCESTON FROM WINDMILL HILL.

St. Andrew's Church with its spire, built in 1850, is the central point of the drawing. Adjacent is the Mechanics Institute, built in 1857, and now the Public Library. Henry Clayton designed both buildings, which still stand.

(No. 14) LAUNCESTON FROM CATARACT HILL.
This shows the town and the pool formed by the junction of the rivers, the North Esk and the South Esk.

(No. 17) LAUNCESTON FROM WHAT IS NOW TREVALLYN.
This shows the signal station on the Windmill Hill and the wharves.

(Trinity Church, corner of George & Cameron Streets)
2(Wesleyan Chapel, Patterson Street.)
3/ Post Office George Street.
4/ Baptist Chapel York Street.
5/ Union Bank, George Street
6/ Roman Catholic Church, George Street
(Public Buildings) Plate No. 9.

(No. 23) OLD TRINITY CHURCH: this was built in 1842 and demolished in 1902. WESLEYAN CHAPEL: this was the first Wesleyan meeting house built in the north of Tasmania. It was opened on Christmas Day 1835. The architect was S. Jackson and the builders Weir and Ferguson. It is now the Sunday School. POST OFFICE: this still stands at 47-55 George Street but a modern front has been added to the lower storey. It was used as a post office from approximately 1839 to 1859. BAPTIST CHAPEL, YORK STREET: this was opened on the 27 November 1840. The pastor, the Reverend Henry Dowling, was the first Baptist Minister in Tasmania. The building still stands, opposite Kingsway, but with the addition of a modern front. It is used now for commercial purposes. UNION BANK, GEORGE STREET: this was opened as the Tamar Bank in 1834 but became the Union Bank in 1838. It was adjacent to the Post Office, shown in (3). It is now incorporated in a business block. ST. JOSEPH'S CHURCH: this was the first Roman Catholic Church in the north of Tasmania. It was opened in 1842 but demolished in 1865.

(No. 25) ST. JOHN'S CHURCH, LAUNCESTON.

Lieutenant-Governor Arthur laid the foundation stone of this church, the first in Northern Tasmania, on the 28 December 1824. Only the tower, completed in 1830, when John Lee Archer was Colonial Architect, remains. On the right is the home of Dr. William Russ Pugh. He, in 1847, administered the first ether anaesthetic in the Southern Hemisphere. The house still stands.

(No. 26) ST. JOHN'S CONGREGATIONAL CHURCH.

This was opeend on the 12 August 1842. When it became too small Christ Church was built next door and the Chapel became, in 1884, the Rev. E. A. Nathan's High School for boys. It is now called Milton Hall and is used for church activities.

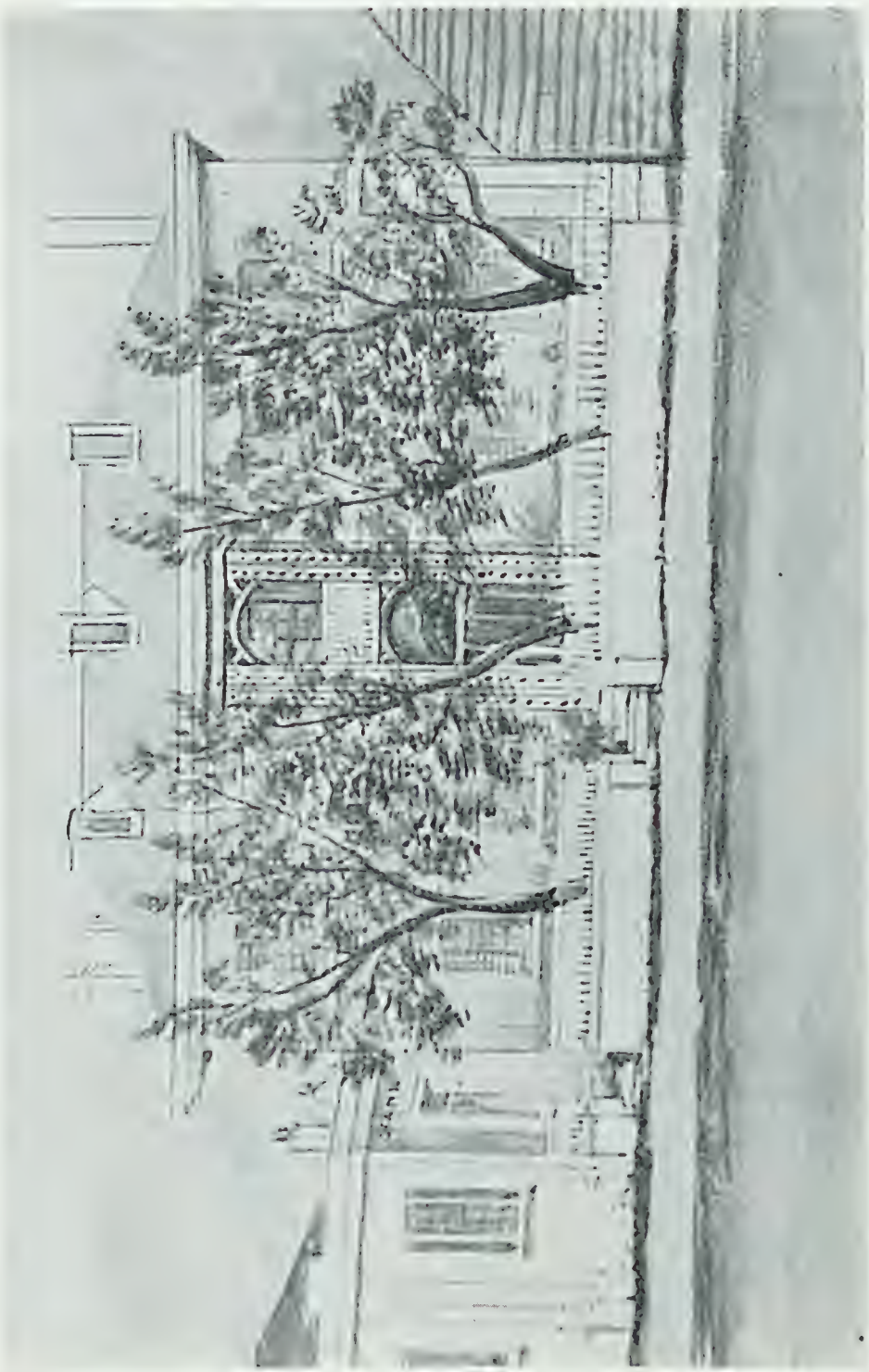
(No. 27) ST. JOHN STREET, LAUNCESTON.

"View taken from opposite the residence of H. Dowling Esq."

Practically all the buildings shown in this drawing remain as surviving examples of Georgian architecture. Mr. Henry Dowling was the leading printer and publisher in Launceston and was prominent in political and civic life.

(No. 28) CAMERON STREET, LAUNCESTON.

The house beyond old Trinity Church was originally named de Little's buildings after its architect and builder. Its present name is Nabowla House.



(No. 29) THE BANK OF TASMANIA.

This was established in 1853. Mr. Francis Evans was the manager until 1873. In 1885 it became the National Bank of Tasmania. The Bank is now the Equitable Building Society and the Northern Club stands on Mr. Evans' residence.

(No. 30) UNION CLUB HOTEL.

This was originally the club house of the 99th Regiment. It became a stage coach terminal. The Duke of Edinburgh stayed here in 1868. Sir Richard Dry had his town residence here. It is demolished.

Papers and Proceedings of the Royal Society of Tasmania, Volume 97

A CHECK LIST OF THE APHIDS OF TASMANIA AND THEIR RECORDED HOST PLANTS

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ABSTRACT

In this first check list of the aphids occurring in Tasmania, 69 species are recorded. Of these 42 have been recorded from both host plants and aphid traps, 12 on host plants only and 15 solely from traps. The host plant list comprises 148 species from 46 botanical families.

INTRODUCTION

Although various species of aphids have been recorded from time to time by previous Government Entomologists (Thompson, 1892 and 1895; Lea, 1908; Evans, 1943) no check list of the aphids occurring in Tasmania has ever been published. When one of us (L.W.M.) initiated a study of the aphid fauna of Tasmania in 1944 there was virtually a complete lack of specimens, identified or not, in the collection of the Tasmanian Department of Agriculture. This was unfortunate as it prevented a direct check from being made on the validity of previous records, some of which on the basis of our present knowledge were certainly erroneous.

Collections from 1944 onwards have greatly increased the number of species known to occur in Tasmania from the 18 species recorded by Evans (1943) to the 69 species now recognized. By 1957 the stage had been reached where the publication of a check list was considered desirable and one of us (E.J.M.) has been engaged since that time in checking the slide and spirit collections and revising the earlier identifications in the light of current usage. An aphid trapping programme initiated in 1960 has also resulted in the discovery of some further species.

This check list is arranged in three sections. The first section is an alphabetical list of aphid species and contains the records of hosts, localities and collection dates; the second is an alphabetical list of host plants and the aphids recorded on them; and the third is an alphabetical list of botanical families and the genera in these families that have been recorded as aphid hosts in Tasmania.

The check list is based on specimens retained in the permanent collection of the Department of Agriculture and host records for which aphid specimens are not available for confirmation of identity have been omitted. The only exception is for some of the aphid trap records where the large bulk of common species has not been retained. The information is complete to December 31st, 1961. Later records have been included only in exceptional instances.

LIST OF APHID SPECIES

1. *Acyrthosiphon pelargonii* (Kalt.) s.str.

   Host: *Erodium moschatum* (L.) Ait.
   Localities: Grove, New Town, Triabunna.
   Collection Dates: Oct., Nov.
   Trap Records: April, June, July, Sept.-Dec.

2. *Acyrthosiphon pisum* (Harris) ssp. *spartii* (Koch).

   Hosts: *Cytisus monspessulanus* L, *Lathyrus* sp.
   Localities: Dynnyrne, Grove, New Town, Sandy Bay, Taroona.
   Collection Dates: June, July, Nov., Dec.
   Trap Records: Oct.-Jan., May.

3. *Acyrthosiphon primulae* (Theo.).

   Host: *Primula* sp.
   Localities: New Town, Taroona.
   Collection Dates: April, July, Oct.
   Trap Records: ——.

4. *Aphis acaenovinae* Eastop.

   Host: ——.
   Localities: Grove, New Town.
   Collection Dates: ——.
   Trap Records: Oct., Dec.

5. *Aphis craccivora* Koch.

   Hosts: *Clianthus puniceus* B. & S., *Lotus* sp., *Phaseolus multiflorus* Willd., *Phaseolus vulgaris* L., *Trifolium repens* L., *Trifolium subterraneum* L., *Vicia faba* L., *Vicia faba* L., var. *minor* Beck., *Vicia sativa* L.
   Localities: Cressy, Grove, Hobart, Kingston, Latrobe, New Town, Sandy Bay, Sorell, Strathblane, Taroona.
   Collection Dates: Feb., March, June, July, Sept., Nov., Dec.
   Trap Records: Aug., Oct.-April.

6. *Aphis gossypii* Glover

Hosts: *Aster* sp., *Bouvardia* sp., *Cassia* sp., *Cucumis sativus* L., *Cucurbita repo* L., *Cyphomandra betacea* Sendt., *Lachenalia tricolor* Thunb., *Photinia* sp., *Sedum* sp.
Localities: Burnie, Grove, Hobart, Launceston, New Town, Sandy Bay, Taroona.
Collection Dates: Jan.-March, June, July, Sept.-Nov.
Trap Records: Sept.-May.

7. *Aphis nerii* B.d.F.

Host: *Asclepias fruticosa* L.
Localities: Hobart, New Town.
Collection Dates: March.
Trap Records: Oct., Dec.-April.

8. *Aphis spiraecola* Patch.

Hosts: *Aster* sp., *Chaenomeles japonica* Lindl., *Cotoneaster* sp., *Hydrangea* sp., *Pyrus communis* L., *Pyrus malus* L., *Spiraea* sp., *Viburnum opulus* L. var. *sterile* DC.
Localities: Devonport, Grove, Hobart, Margate, New Town, Premaydena, Ranelagh, Sandy Bay.
Collection Dates: Jan.-March, May, July, Nov.
Trap Records: Sept.-June.

9. *Aphis* sp.

Host: ——.
Locality: Grove.
Collection Dates: ——.
Trap Records: Jan.

10. *Aploneura lentisci* (Pass.).

Hosts: *Bromus mollis* L. (roots), *Lolium perenne L.* (roots), *Ribes nigrum* L. (roots).
Localities: Grove, Hayes, Margate, New Town, Ouse.
Collection Dates: March, June, Oct., Dec.
Trap records: Nov.-March.

11. *Aulacorthum solani* (Kalt.).

Hosts: *Campanula medium* L., *Lathyrus* sp., *Physostegia* sp., *Senecio* sp., *Solanum tuberosum* L.
Localities: Dynnyrne, Grove, Hobart, New Town, Pittwater, Tewkesbury.
Collection Dates: Jan., July, Oct., Dec.
Trap Records: Sept.-June.

12. *Aulacorthum* (*Neomyzus*) *circumflexum* (Buckton).

Hosts: *Adiantum* sp., *Cymbidium* sp., *Oxalis corniculata* L., *Vicia* sp.
Localities: Sandy Bay, Taroona.
Collection Dates: May, July, Aug., Oct.
Trap Records: ——.

13. *Brachycaudus helichrysi* (Kalt.).

Hosts: *Aster* sp., *Bedfordia salicina* DC., *Carduus pycnocephalus* L., *Centaurea cyanus* L., *Chamaecytisus proliferus* (L.f.) Link., *Chrysanthemum* sp., *Cotula coronopifolia* L., *Cytisus* sp., *Dahlia* sp., *Daisy* (Compositae), *Erechthites quadridentata* (Labill.) DC., *Helianthus annuus* L., *Hibiscus* sp., *Senecio cruentus* DC., *Senecio* sp., *Trifolium pratense* L., *Veronica* sp., *Vicia faba* L.
Localities: Cressy, Grove, Hobart, Launceston, Lenah Valley, Longley, Lutana, Margate, Mt. Stuart, Mt. Wellington (c. 1000 ft.), New Town, Pittwater, Rosny Pt., Sandy Bay, Summerleas, Taroona, Tewkesbury.
Collection Dates: March, April, June, Aug.-Jan.
Trap Records: April-Jan.

14. *Brachycaudus persicaecola* (Boisd.).

Hosts: *Prunus persica* Sieb. & Zucc., *Prunus salicina* Lindl.
Localities: Dynnyrne, Hobart, New Town, Somerset.
Collection Dates: Sept., Oct.
Trap Records: Oct.-Dec.

15. *Brevicoryne brassicae* (L.).

Hosts: *Brassica chinensis* L., *Brassica oleracea* L., *Brassica oleracea* L. var. *ramosa* Alef., *Cardaria draba* (L.) Desv.
Localities: Grove, Hobart, New Town, Richmond, Summerleas.
Collection Dates: March, April, July, Sept., Oct.
Trap Records: Aug.-June.

16. *Capitophorus elaeagni* (del Guercio).

Hosts: *Carduus pycnocephalus* L., *Cirsium arvense* (L.) Scop., *Cirsium vulgare* (Savi) Ten., *Cryptostemma calendula* (L.) Druce.
Localities: Bridgewater, Cambridge, Cressy, Douglas River, Freshwater Point, Grove, Launceston, New Town.
Collection Dates: May-July.
Trap Records: Oct.-June.

17. *Cavariella aegopodii* (Scop.).

Hosts: *Apium graveolens* L., *Daucus carota* L., *Foeniculum vulgare* Mill., *Pastinaca sativa L.*, *Petroselinum crispum* (Mill.) Nym., *Salix* sp.
Localities: Cressy, Glenorchy, Grove, Hobart, Howrah, Launceston, New Norfolk, New Town, Summerleas, Taroona.
Collection Dates: March-June, Oct.-Jan.
Trap Records: Jan.-Dec.

18. *Chaetosiphon* (*Pentatrichopus*) *fragaefolii* (Ckll.).

Host: *Fragaria* sp. cult.
Localities: Blessington, Hobart, New Town, Snug.
Collection Dates: Jan., March, Aug., Nov.
Trap Records: June, Nov.

19. *Chaetosiphon* (*Pentatrichopus*) *tetrarhodum* (Walker).

Hosts: *Rosa rubiginosa* L., *Rosa* sp. cult.
Localities: Grove, Hobart, Lenah Valley, New Town, Summerleas, Ulverstone.
Collection Dates: April, Sept., Nov.
Trap Records: May, Oct.-Dec.

20. *Cinara* (*Cupressobium*) *cupressi* (Buckton).
Host: *Cupressus macrocarpa* Gord.
Localities: Claremont, Hobart, New Town, Sandy Bay.
Collection Dates: April, June, Aug., Sept.
Trap Records: Oct.

21. *Cinara* (*Cupressobium*) *tujafilina* (del Guer.) species group.
Host: *Callitris tasmanica* (Benth.) B. & S.
Locality: Coles Bay.
Collection Date: May.
Trap Records: ——.

22. *Cinara* sp.
Host:*Picea* sp.
Locality: Oatlands.
Collection Date: May (Specimens immature).
Trap Records: ——.

23. *Coloradoa rufomaculata* (Wilson).
Host: *Chrysanthemum* sp.
Locality: Hobart.
Collection Date: April.
Trap Records: ——.

24. *Drepanosiphum platanoides* (Schr).
Host: *Acer pseudoplatanus* L.
Localities: Hobart, New Town.
Collection Dates. April.
Trap Records: Feb.-June, Oct.-Dec.

25. *Dysaphis apiifolia* (Theo.).
Host: ——.
Locality: New Town.
Collection Dates: ——
Trap Records: Jan., June.

26. *Dysaphis foeniculus* (Theo.).
Host: *Daucus carota* L.
Localities: Hobart, New Town.
Collection Dates: Feb., Dec.
Trap Records: Oct.-May.

27. *Dysaphis tulipae* (B.d.F.).
Host: ——.
Locality: New Town.
Collection Dates: ——.
Trap Records: Feb., March, Oct.-Dec.

28. *Elatobium abietinum* (Walker).
Hosts: *Callitris tasmanica* (Benth.) B. & S., *Picea excelsa* Link, *Picea* sp.
Localities: Coles Bay, Oatlands.
Collection Dates: May, Sept.
Trap Records: ——.

29. *Eriosoma flavum* Jancke.
Host: ——.
Locality: New Town.
Collection Dates: ——
Trap Records: Jan., April.

30. *Eriosoma lanigerum* (Hausmann).
Host: *Pyrus malus* L.
Localities: Elderslie, Geeveston, Hayes, Margate, New Town, Ranelagh.
Collection Dates: March-May, Dec.
Trap Records: ——.

31. *Eriosoma lanuginosum* (Hartig).
Hosts: *Pyrus communis* L. (roots), *Ulmus campestris* L.
Localities: Cambridge, Castle Forbes Bay, Claremont, Grove, New Town, Ranelagh.
Collection Dates: Sept., Dec.-April.
Trap Records: Dec.-April.

32. *Euceraphis punctipennis* (Zett.).
Host: *Betula alba* L.
Localities: New Town, Taroona.
Collection Dates: April, Sept.
Trap Records: Sept.-July.

33. *Hyadaphis foeniculi* (Pass.).
Hosts: *Daucus carota* L., *Lonicera* sp., *Petroselinum crispum* (Mill.) Nym.
Localities: Glenorchy, Hobart, New Town, Summerleas, Taroona.
Collection Dates: April, Oct.-Dec.
Trap Records: Feb.-April, Oct.

34. *Hyalopterus arundinis* (F.).
Host: ——.
Localities: Grove, New Town.
Collection Dates: ——.
Trap Records: March-May, Dec.

35. *Hyperomyzus lactucae* (L.).
Hosts: *Ribes nigrum* L., *Ribes* sp., *Sonchus oleraceus* L.
Localities: Grove, Hobart, New Town, Ranelagh, Sandy Bay, Summerleas, Taroona.
Collection Dates: Nov., Dec.
Trap Records: Jan.-Dec.

36. *Idiopterus nephrelepidis* Davis.
Host: *Adiantum* sp.
Localities: Hobart, New Town.
Collection Dates: March, April, Sept.
Trap Records: ——.

37. *Kallistaphis basalis* Stroyan.
Host: *Betula alba* L.
Localities: Grove, New Town, Sandy Bay.
Collection Dates: April, Sept.
Trap Records: April-June, Oct.-Dec.

38. *Liosomaphis berberidis* (Kalt.).
Host: ——.
Locality: New Town.
Collection Dates: ——.
Trap Records: Oct., Nov.

39. *Lipaphis pseudobrassicae* (Davis).
Hosts: *Brassica rapa* L. (roots), *Raphanus raphanistrum* L., *Sinapis arvensis* L.
Localities: Bridgewater, Grove, New Town, South Riana.
Collection Dates: March, June, Oct.
Trap Records: Oct.-April.

40. *Macrosiphoniella sanborni* (Gill.).
Host: *Chrysanthemum* sp.
Localities: Hobart, Launceston, New Town.
Collection Dates: April, May, Aug.
Trap Records: April, May, Oct.

41. *Macrosiphum euphorbiae* (Thomas).

Hosts: *Antirrhinum majus* L., *Bouvardia* sp., *Calendula* sp., *Campanula medium* L., *Capsicum* sp., *Cardaria draba* (L.) Desv., *Cassinia* sp., *Chenopodium album* L., *Cotula coronopifolia* L., *Cucurbita pepo* L., *Erodium moschatum* (L) Ait., *Fragaria* sp. cult., *Galium aparine* L., *Humulus lupulus* L., *Hydrangea* sp., *Iris* sp., *Kentranthus ruber* (L.) DC., *Lachenalia* sp., *Lactuca sativa* L., *Leptosyne* sp., *Leucopogon richei* R.Br., *Lycopersicon esculentum* Mill., *Myosotis scorpioides* L., *Narcissus* sp., *Oxalis corniculata* L., *Phaseolus vulgaris* L., *Physostegia* sp., *Pisum sativum* L., *Potentilla* sp., *Primula* sp., *Rosa rubiginosa* L., *Rosa* sp. cult., *Rubus idaeus* L., *Rumex crispus* L., *Senecio* sp., *Solanum marginatum* L.f., *Solanum tuberosum L.*, *Sonchus asper* (L.) Hill, *Sonchus oleraceus* L., *Tropaeolum majus* L., *Tulipa* sp.
Localities: Austin's Ferry, Grove, Hayes, Hobart, Launceston, Lenah Valley, Longley, Mt. Stuart, Myrtle Bank, New Norfolk, New Town, Richmond, Sandy Bay, South Arm, South Bruny Island, Summerleas, Taroona, Tewkesbury, Triabunna, Tunnack, Ulverstone.
Collection Dates: Jan.-Dec.
Trap Records: July-May.

42. *Macrosiphum rosae* (L.).

Hosts: *Rosa rubiginosa* L., *Rosa* sp. cult.
Localities: Hobart, Lenah Valley, New Town, Sandy Bay, Summerleas, Taroona.
Collection Dates: April, June, Aug., Sept., Nov.
Trap Records: March, April, Sept.-Nov.

43. *Macrosiphlum* (*Sitobion*) *avenae* (F.) ssp. *miscanthi* Takahashi.

Host: *Primula* sp.
Localities: Grove, New Town.
Collection Dates: Oct.
Trap Records: Oct., Dec.-Feb.

44. *Myzocallis annulata* (Hartig).

Host: *Quercus* sp.
Localities: Cambridge, Cradoc, Grove, Hobart, New Town.
Collection Dates: Oct., Nov.
Trap Records: Oct.-May.

45. *Myzocallis castanicola* Baker.

Host: *Quercus* sp.
Localities: Hobart, New Town.
Collection Dates: Sept., Oct.
Trap Records: March-June, Oct.-Dec.

46. *Myzocallis coryli* (Goetze).

Hosts: *Corylus colurna* L., *Corylus* sp.
Localities: Hobart, Huonville, New Town.
Collection Dates: May.
Trap Records: Oct.

47. *Myzus ascalonicus* Donc.

Host: ——.
Locality: New Town.
Collection Dates: ——.
Trap Records: Oct.

48. *Myzus cerasi* (F).

Hosts: *Galium aparine* L., *Prunus cerassus* L.
Localities: Grove, Molesworth, New Town, Premaydena, Taroona.
Collection Dates: Oct., Nov.
Trap Records: March, April, July-Nov.

49. *Myzus cymbalariae* Stroyan.

Hosts: *Allium ascalonicum* L., *Euphorbia peplus* L., *Rumex crispus* L., *Stellaria media* (L.) Vill., *Trifolium repens* L., *Vicia* sp., *Viola tricolor* L. var. *hortensis* DC.
Localities: Grove, New Town, Taroona.
Collection Dates: July-Sept.
Trap Records: July-Nov.

50. *Myzus ornatus* Laing.

Hosts: *Calceolaria* sp., *Daucus carota* L., *Euphorbia peplus* L., *Fuchsia* sp., *Hydrangea* sp., *Impatiens balsamina* L., *Medicago sativa* L., *Mentha spicata* L., *Pelargonium* sp., *Petroselinum crispum* (Mill.) Nym., *Rumex crispus* L., *Sanchezia* sp., *Senecio cruentus* DC., *Stellaria media* (L.) Vill., *Trifolium repens* L., *Veronica* sp., *Vigna sinensis* (L.) Endl., *Viola tricolor* var. *hortensis* DC.
Localities: Grove, Hobart, Lenah Valley, Mt. Stuart, New Town, Sandy Bay, Summerleas, Taroona.
Collection Dates: April, June-Oct., Dec.
Trap Records: Feb.-Dec.

51. *Myzus persicae* (Sulz.).

Hosts: *Althaea rosa* Cav., *Asclepias fruticosa* L., *Bouvardia* sp., *Brassica oleracea* L. var., *ramosa* Alef., *Capsicum* sp., *Cotula coronopifolia* L., *Cryptostemma calendula* (L.) Druce, *Datura stramonium* L., *Erodium moschatum* (L.) Ait., *Euphorbia peplus* L., *Hebe hulkeana* F.v.M., *Humulus lupulus* L., *Lactuca sativa* L., *Lycium ferocissimum* Miers, *Lycopersicon esculentum* Mill., *Matthiola incana* R.Br., *Pisum sativum* L., *Prunus persica* Sieb. & Zucc., *Prunus* sp., *Sinapis arvensis* L., *Solanum tuberosum* L., *Tulipa* sp., *Vicia faba* L.
Localities: Bridgewater, Freshwater Point, Glenorchy, Grove, Hayes, Hobart, Launceston, Lenah Valley, Lindisfarne, Mangalore, New Norfolk, New Town, Richmond, Rose Bay, Sandy Bay, Scottsdale, Somerset, Taroona, Tewkesbury.
Collection Dates: Sept.-July.
Trap Records: Jan.-Dec.

52. *Neotoxoptera oliveri* (Essig).

Host: ——.
Locality: New Town.
Collection Dates: ——.
Trap Records: Aug., Oct.

53. *Ovatus crataegarius* (Walker).

Host: *Mentha spicata* L.
Localities: Grove, Hobart, New Town.
Collection Dates: Oct., Dec.
Trap Records: Oct., Nov.

54. *Pemphigus bursarius* (L.).
Hosts: *Populus nigra* L., var. *italica* Du Roi, *Rumex acetosella* L. (roots), *Rumex* sp. (roots), *Taraxacum officinale* Weber (roots).
Localities: Dilston, Glenora, Grove, Hobart, Margate, New Town, Ranelagh, Sandy Bay.
Collection Dates: March, April, July, Nov., Dec.
Trap Records: Nov.-May.

55. *Periphyllus californiensis* (Shinji).
Host: *Acer* sp.
Localities: New Town, Sandy Bay.
Collection Dates: Oct.
Trap Records: Sept., Oct.

56. *Phyllaphis fagi* (L.).
Host: *Fagus sylvatica* L. var. *purpurea* Ait.
Localities: Hobart, Launceston, New Town.
Collection Dates: April, Nov.
Trap Records: Oct., Nov.

57. *Pineus* sp.
Host: *Pinus radiata* Don.
Localities: Bruny Is., Gravelly Beach.
Collection Dates: Sept.
Trap Records: ——.

58. *Rhopalosiphoninus latysiphon* (Davidson).
Host: ——.
Locality: Grove.
Collection Dates: ——.
Trap Records: Feb.

59. *Rhopalosiphoninus staphyleae* (Koch).
Host: *Oxalis corniculata* L.
Localities: Grove, New Town, Taroona.
Collection Dates: July.
Trap Records: April, Aug., Sept., Nov.-Jan.

60. *Rhopalosiphum maidis* (Fitch).
Hosts: *Sorghum vulgare* Pers., *Zea mays* L.
Localities: Elderslie, Scottsdale.
Collection Dates: March, May.
Trap Records: ——.

61. *Rhopalosiphum nymphaeae* (L.).
Host: *Dianella tasmanica* Hook.
Localities: Blackman's Bay, Grove.
Collection Dates: Oct.
Trap Records: April.

62. *Rhopalosiphum padi* (L.).
Hosts: *Avena sativa* L., *Hordeum vulgare* L., *Lolium perenne* L., *Secale cereale* L.
Localities: Cressy, Elliott, Grove, New Town, Penguin, Rokeby, Springfield.
Collection Dates: June, Sept.-Dec.
Trap Records: Jan.-Dec.

63. *Rhopalosiphum rufiabdominalis* (Sasaki).
Host: ——.
Localities: Grove, New Town.
Collection Dates: ——.
Trap Records: April, Nov.-Jan.

64. *Sensoriaphis tasmaniae* Carver & Martyn.
Host: *Nothofagus cunninghamii* Oer.
Locality: Fern Tree.
Collection Dates: Jan., May, July, Dec.
Trap Records: ——.

65. *Smynthurodes betae* Westwood.
Hosts: *Phaseolus vulgaris* L. (roots), *Portulaca* sp. (roots).
Localities: Abbotsham, Kingston.
Collection Dates: April, June.
Trap Records: ——.

66: *Toxoptera aurantii* (B.d.F.).
Host: ——.
Locality: New Town.
Collection Dates: ——.
Trap Records: Dec.

67. Unidentified—new genus and species?
Host: ——.
Locality: New Town.
Collection Dates: ——.
Trap Records: Feb.

LIST OF HOST PLANTS

Acer pseudoplatanus L.
Drepanosiphum platanoides (Schr.).
Acer sp.
Periphyllus californiensis (Shinji).
Adiantum sp.
Aulacorthum (Neomyzus) circumflexum (Buckton).
Idiopterus nephrelepidis Davis.
Allium ascalonicum L.
Myzus cymbalariae Stroyan.
Althaea rosea Cav.
Myzus persicae (Sulz.).
Antirrhinum majus L.
Macrosiphum euphorbiae (Thom.).
Apium graveolens L.
Cavariella aegopodii (Scop.)
Asclepias fruticosa L.
Aphis nerii B.d.F.
Myzus persicae (Sulz.).
Aster sp.
Aphis gossypii Glover.
Aphis spiraecola Patch.
Brachycaudus helichrysi (Kalt.).
Avena sativa L.
Rhopalosiphum padi (L.).
Bedfordia salicina DC.
Brachycaudus helichrysi (Kalt).
Betula alba L.
Euceraphis punctipennis (Zett.).
Kaltistaphis vasalis Stroyan.
Bouvardia sp.
Aphis gossypii Glover.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Brassica chinensis L.
Brevicoryne brassicae (L.).
Brassica oleracea L.
Brevicoryne brassicae (L.).
Brassica oleracea L. var. *ramosa* Alef.
Brevicoryne brassicae (L.).
Myzus persicae (Sulz.).

Brassica rapa L.
Lipophis pseudobrassicae (Davis).
Bromus mollis L.
Aploneura lentisci (Pass.).
Calceolaria sp.
Myzus ornatus Laing.
Calendula sp.
Macrosiphum euphorbiae (Thom.).
Callitris tasmanica (Benth.) B. & S.
Cinara (Supressobium) tujafilina (del Guer.) species group.
Elatobium abietinum (Walk.).
Campanula medium L.
Aulacorthum solani (Kalt.).
Macrosiphum euphorbiae (Thom.).
Capsicum sp.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Cardaria draba (L.) Desv.
Brevicoryne brassicae (L.).
Macrosiphum euphorbiae (Thom.).
Carduus pycnocephalus L.
Brachycaudus helichrysi (Kalt.).
Capitophorus elaeagni (del Guer.).
Cassia sp.
Aphis gossypii Glover.
Cassinia sp.
Macrosiphum euphorbiae (Thom.).
Centaurea cyanus L.
Brachycaudus helichrysi (Kalt.).
Chaenomeles japonica Lindl.
Aphis spiraecola Patch.
Chamaecytisus proliferus (L.f.) Link.
Brachycaudus helichrysi (Kalt.).
Chenopodium album L.
Macrosiphum euphorbiae (Thom.).
Chrysanthemum sp.
Brachycaudus helichrysi (Kalt.).
Coloradoa rufomaculata (Wilson.).
Macrosiphoniella sanborni (Gill.).
Cirsium arvense (L.) Scop.
Capitophorus elaeagni (del Guer.).
Cirsium vulgare (Savi) Ten.
Capitophorus elaeagni (del Guer.).
Clianthus punicea B. & B.
Aphis craccivora Koch.
Corylus colurna L.
Myzocallis coryli (Goetze).
Corylus sp.
Myzocallis coryli (Goetze).
Cotoneaster sp.
Aphis spiraecola Patch.
Cotula coronopifolia L.
Brachycaudus helichrysi (Kalt.).
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Cryptostemma calendula (L.) Druce.
Capitophorus elaeagni (del Guel.).
Myzus persicae (Sulz.).
Cucumis sativus L.
Aphis gossypii Glover.
Cucurbita pepo L.
Aphis gossypii Glover.
Macrosiphum euphorbiae (Thom.).
Cupressus macrocarpa Gord.
Cinara (Cupressobium) cupressi (Buck.).
Cymbidium sp.
Aulacorthum (Neomyzus) circumflexum (Buck.).
Cyphomandra betacea Sendt.
Aphis gossypii Glover.
Cytisus monspessulanus L.
Acyrthosiphon pisum (Harris) ssp. *spartii* (Koch).
Cytisus sp.
Brachycaudus helichrysi (Kalt.).
Dahlia sp.
Brachycaudus helichrysi (Kalt.).
Daisy (fam. Compositae).
Brachycaudus helichrysi (Kalt.).
Datura stramonium L.
Myzus persicae (Sulz.).
Daucus carota L.
Cavariella aegopodii (Scop.).
Dysaphis foeniculus (Theo.).
Hyadaphis foeniculi (Pass.).
Myzus ornatus Laing.
Dianella tasmanica Hook.
Rhopalosiphum nymphaeae (L.).
Erechthites quadridentata (Labill.) DC.
Brachycaudus helichrysi (Kalt.).
Erodium moschatum (L.) Ait.
Acyrthosiphon pelargonii (Kalt.) s.str.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Euphorbia peplus L.
Myzus cymbalariae Stroyan.
Myzus ornatus Laing.
Myzus persicae (Sulz.).
Fagus sylvatica L. var. *purpurea* Ait.
Phyllaphis fagi (L.).
Foeniculum vulgare Mill.
Cavariella aegopoddi (Scop.).
Fragaria sp. cult.
Chaetosiphon (Pentatrichopus) fragaefolii (Ckll.).
Macrosiphum euphorbiae (Thom.).
Fuchsia sp.
Myzus ornatus Laing.
Galium aparine L.
Macrosiphum euphorbiae (Thom.).
Myzus cerasi (F.).
Hebe hulkeana F.v.M.
Myzus persicae (Sulz.).
Helianthus annuus L.
Brachycaudus helichrysi (Kalt.).
Hibiscus sp.
Brachycaudus helichrysi (Kalt.).
Hordeum vulgare L.
Rhopalosiphum padi (L.).
Humulus lupulus L.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Hydrangea sp.
Aphis spiraecola Patch.
Macrosiphum euphorbiae (Thom.).
Myzus ornatus Laing.
Impatiens balsamina L.
Myzus ornatus Laing.
Iris sp.
Macrosiphum euphorbiae (Thom.).
Kentranthus ruber (L.) DC.
Macrosiphum euphorbiae (Thomas).
Lachenalia tricolor Thunb.
Aphis gossypii Glov.
Lachenalia sp.
Macrosiphum euphorbiae (Thom.).

Lactuca sativa L.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Lathyrus sp.
Acyrthosiphon pisum (Harris) ssp. *spartii* (Koch).
Aulacorthum solani (Kalt.).
Leptosyne sp.
Macrosiphum euphorbiae (Thom.).
Leucopogon richei R.Br.
Macrosiphum euphorbiae (Thom.).
Lolium perenne L.
Aploneura lentisci (Pass.).
Rhopalosiphum padi (L.).
Lonicera sp.
Hyadaphis foeniculi (Pass.).
Lotus sp.
Aphis craccivora Koch.
Lycium ferocissimum Miers
Myzus persicae (Sulz.).
Lycopersicon esculentum Mill.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Matthiola incana R.Br.
Myzus persicae (Sulz.).
Medicago sativa L.
Myzus ornatus Laing.
Mentha spicata L.
Myzus ornatus Laing.
Ovatus crataegarius (Walk.).
Myosotis scorpioides L.
Macrosiphum euphorbiae (Thom.).
Narcissus sp.
Macrosiphum euphorbiae (Thom.).
Nothofagus cunninghamii Oer.
Sensoriaphis tasmaniae Carver & Martyn.
Oxalis corniculata L.
Aulacorthum (*Neomyzus*) *circumflexum* (Buck.).
Macrosiphum euphorbiae (Thom.).
Rhopalosiphoninus staphyleae (Koch).
Pastinaca sativa L.
Cavariella aegopodii (Scop.).
Pelargonium sp.
Myzus ornatus Laing.
Petroselinum crispum (Mill.) Nym.
Cavariella aegopodii (Scop.).
Hyadaphis foeniculi (Pass.).
Myzus ornatus Laing.
Phaseolus multiflorus Willd.
Aphis craccivora Koch.
Phaseolus vulgaris (L).
Aphis craccivora Koch.
Macrosiphum euphorbiae (Thom.).
Smynthurodes betae (Wwd.).
Photinia sp.
Aphis gossypii Glover.
Physostegia sp.
Aulacorthum solani (Kalt.).
Macrosiphum euphorbiae (Thom.).
Picea excelsa Link.
Elatobium abietinum (Walk.).
Picea sp.
Cinara sp.
Elatobium abietinum (Walk.).
Pinus radiata Don.
Pineus sp.
Pisum sativum L.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Populus nigra L. var. *italica* Du Roi.
Pemphigus bursarius (L.).
Portulaca sp.
Smythurodes betae (Wwd.).
Potentilla sp.
Macrosiphum euphorbiae (Thom.).
Primula sp.
Acyrthosiphon primulae (Theo.).
Macrosiphum euphorbiae (Thom.).
Macrosiphum (*Sitobion*) *avenae* (F.) ssp. *miscanthi* Tak.
Prunus cerasus L.
Myzus cerasi (F.).
Prunus persica Sieb. & Zucc.
Brachycaudus persicaecola (Boisd.).
Myzus persicae (Sulz.).
Prunus salicina Lindl.
Brachycaudus persicaecola (Boisd.).
Prunus sp.
Myzus persicae (Sulz.).
Pyrus communis L.
Aphis spiraecola Patch.
Eriosoma lanuginosum (Htg.).
Pyrus malus L.
Aphis spiraecola Patch.
Erisoma lanigerum (Hausm.).
Quercus sp.
Myzocallis annulata (Htg.).
Myzocallis castanicola Baker.
Raphanus raphanistrum L.
Lipaphis pseudobrassicae (Davis).
Ribes nigrum L.
Aploneura lentisci (Pass.).
Hyperomyzus lactucae (L.).
Ribes sp.
Hyperomyzus lactucae (L.).
Rosa rubiginosa L.
Chaetosiphon (*Pentatrichopus*) *tetrarhodum* (Walk.).
Macrosiphum euphorbiae (Thom.).
Macrosiphum rosae (L.).
Rosa sp. cult.
Chaetosiphon (*Pentatrichopus*) *tetrarhodum* (Walk.).
Macrosiphum euphorbiae (Thom.).
Macrosiphum rosae (L.).
Rubus idaeus L.
Macrosiphum euphorbiae (Thom.).
Rumex acetosella L.
Pemphigus bursarius (L.).
Rumex crispus L.
Macrosiphum euphorbiae (Thom.).
Myzus cymbalariae Stroyan.
Myzus ornatus Laing.
Rumex sp.
Pemphigus bursarius (L.).
Salix sp.
Cavariella aegopodii (Scop.).
Sanchezia sp.
Myzus ornatus Laing.
Secale cereale L.
Rhopalosiphum padi (L.).
Sedum sp.
Aphis gossypii Glover.

Senecio cruentus DC.
Brachycaudus helichrysi (Kalt.).
Myzus ornatus Laing.
Senecio sp.
Aulacorthum solani (Kalt.).
Brachycaudus helichrysi (Kalt.).
Macrosiphum euphorbiae (Thom.).
Sinapis arvensis L.
Pipaphis pseudobrassicae (Davis).
Myzus persicae (Sulz.).
Solanum marginatum L.f.
Macrosiphum euphorbiae (Thom.).
Solanum tuberosum L.
Aulacorthum solani (Kalt.).
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Sonchus asper (L.) Hill.
Macrosiphum euphorbiae (Thom.).
Sonchus oleraceus L.
Hyperomyzus lactucae (L.).
Macrosiphum euphorbiae (Thom.).
Sorghum vulgare Pers.
Rhopalosiphum maidis (Fitch).
Spiraea sp.
Aphis spiraecola Patch.
Stellaria media (L.) Vill.
Myzus cymbalariae Stroyan.
Myzus ornatus Laing.
Taraxacum officinale Weber.
Pemphigus bursarius (L.).
Trifolium pratense L.
Brachycaudus helichrysi (Kalt.).
Trifolium subterraneum L.
Aphis craccivora Koch.
Myzus cymbalariae Stroyan.
Myzus ornatus Laing.
Trifolium subterraneun L.
Aphis craccivora Koch.
Tropaeolum majus L.
Macrosiphum euphorbiae (Thom.).
Tulipa sp.
Macrosiphum euphorbiae (Thom.).
Myzus persicae (Sulz.).
Ulmus campestris L.
Eriosoma lanuginosum (Htg.).
Veronica sp.
Brachycaudus helichrysi (Kalt.).
Myzus ornatus Laing.
Viburnum opulus L. var. *sterile* DC.
Aphis spiraecola Patch.
Vicia faba L.
Aphis craccivora Koch.
Brachycaudus helichrysi (Kalt.).
Myzus persicae (Sulz.).
Vicia faba L. var. *minor* Beck.
Aphis craccivora Koch.
Vicia sativa L.
Aphis craccivora Koch.
Vicia sp.
Aulacorthum (Neomyzus) circumflexum (Buck.).
Myzus cymbalariae Stroyan.
Vigna sinensis (L.) Endl.
Myzus ornatus Laing.
Viola tricolor L. var. *hortensis* DC.
Myzus cymbalariae Stroyan.
Myzus ornatus Laing.
Zea mays L.
Rhopalosiphum maidis (Fitch).

BOTANICAL FAMILIES—GENERA RECORDED AS HOST PLANTS

Acanthaceae.
Sanchezia.
Aceraceae.
Acer.
Amaryllidaceae.
Narcissus.
Asclepiadaceae.
Asclepias.
Balsaminaceae.
Impatiens.
Betulaceae.
Betula, Corylus.
Boraginaceae.
Myosotis.
Campanulaceae.
Campanula.
Caprifoliaceae.
Lonicera, Viburnum.
Caryophyllaceae.
Stellaria.
Chenopodiaceae.
Chenopodium.
Compositae.
Aster, Bedfordia, Calendula, Carduus, Cassinia, Centaurea, Chrysanthemum, Cirsium, Cotula, Cryptostemma, Dahlia, Daisy, *Erechthites, Helianthus, Lactuca, Leptosyne, Senecio, Sonchus, Taraxacum.*
Crassulaceae.
Sedum.
Cruciferae.
Brassica, Cardaria, Matthiola, Raphanus, Sinapis.
Cucurbitaceae.
Cucumis, Cucurbita.
Cupressaceae.
Callitris, Cupressus.
Epacridaceae.
Leucopogon.
Euphorbiaceae.
Euphorbia.
Fagaceae.
Fagus, Nothofagus, Quercus.
Geraniaceae.
Erodium, Pelargonium.
Gramineae.
Avena, Bromus, Hordeum, Lolium, Secale, Sorghum, Zea.
Iridaceae.
Iris.
Labiatae.
Mentha, Physostegia.
Leguminosae.
Cassia, Chamaecytisus, Clianthus, Cytisus, Lathyrus, Lotus, Medicgo, Phaseolus. Pisum, Trifolium, Vicia, Vinga.
Liliaceae.
Allium, Dianella, Lachenalia, Tulipa.
Malvaceae.
Althaea, Hibiscus.
Moraceae.
Humulus.
Onagraceae.
Fuchsia.
Orchidaceae.
Cymbidium.

Oxalidaceae.
Oxalis.

Pinaceae.
Picea, Pinus.

Polygonaceae.
Rumex.

Polypodiaceae.
Adiantum.

Portulacaceae.
Portulaca.

Primulaceae.
Primula.

Rosaceae.
Chaenomeles, Cotoneaster, Fragaria, Photinia, Potentilla, Prunus, Pyrus, Rosa, Rubus, Spiraea.

Rubiaceae.
Bouvardia, Gallium.

Salicaceae.
Populus, Salix.

Saxifragaceae.
Hydrangea, Ribes.

Scrophulariaceae.
Antirrhinum, Calceolaria, Hebe, Veronica.

Solanaceae.
Capsicum, Cyphomandra, Datura, Lycium, Lycopersicon, Solanum.

Tropaeolaceae.
Tropaeolum.

Ulmaceae.
Ulmus.

Umbelliferae.
Apium, Daucus, Foeniculum, Pastinaca, Petroselinum.

Valerianaceae.
Kentranthus.

Violaceae.
Viola.

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ADDENDUM

Since the manuscript was prepared two additional species have been recorded. The details are as follows:—

Anomalaphis sp.
Host: ——.
Locality: Grove.
Collection Dates: ——.
Trap records: March.

Pleotrichophorus glandulosus (Kalt.) ssp. *chrysanthemi* (Theo.).
Host: ——.
Localities: Grove, New Town.
Collection Dates: ——.
Trap Records: March, April.

Map of Tasmania showing localities of aphid collections; Inset—Hobart and surrounding districts.

THE OCCURRENCE IN TASMANIA OF THE LAND NEMERTINE, GEONEMERTES AUSTRALIENSIS DENDY, WITH SOME ACCOUNT OF ITS DISTRIBUTION, HABITS, VARIATIONS AND DEVELOPMENT.

By

V. V. Hickman

(With two plates and 20 figures in the text)

ABSTRACT

The terrestrial nemertine, *Geonemertes australiensis* Dendy, is widely distributed in Tasmania, but is never found in large numbers. It occurs in cool and moist situations from near sea-level to the summit of mountains 4000 ft. in height. The sexes are separate. Males reach a maximum length of about 60 mm. and females about 84 mm. The colour varies from pale cream to reddish brown. Some specimens are blotched with brown, others are marked with longitudinal dark brownish stripes. The nemertine feeds on young myriapods and small insects, particularly Collembola, which it captures with its proboscis and kills with its stylet. The eyes vary in number from four in recently hatched specimens to over 170 in some adults. The number of proboscidial nerves is established before hatching. An examination of 187 adults and 374 young shows the number to vary from 11 to 21, the most frequent number being 14. Two reserve stylet pouches are present in young specimens that have just emerged from the egg-capsule but as many as 11 may be present in adults.

The gelatinous egg-capsules are deposited under logs, stones, moss, fallen leaves, &c. They vary in size from 8.0 mm. x 4.0 mm. to 48.0 mm. x 10.0 mm. Small capsules may contain only four eggs, whereas large ones may contain several hundred. One female may deposit as many as seven capsules in a period of two months. Egg laying occurs throughout the year but appears to be most active in April and May. At a temperature of 13° C. the eggs hatch in the gelatinous matrix in about 15 days, but the newly hatched young are in a very immature condition and remain in the capsule for another 24 days.

In the early stages of development cleavage is holoblastic, equal and of the spiral type. A typical hollow blastula is formed. Gastrulation is brought about by the ingression of blastomeres into the blastocoel at the vegetative pole. At the same time cells separate off from the inner ends of the blastomeres forming the wall of the blastula and fall into the blastocoel. These cells constitute mesectoderm. The blastocoel becomes filled with a mass of cells and its lumen obliterated. The outer ends of the blastomeres remain as large yolky cells surrounding the embryo and supply nourishment to the proliferating mesectoderm.

INTRODUCTION

The terrestrial nemertine, *Geonemertes australiensis* Dendy, was first recorded from Gippsland, Victoria, by Dendy in 1889 and described by him in 1892. Fletcher mentioned the occurrence of land nemertines in Tasmania and New South Wales in 1891. He sent two specimens from these localities to Dendy, who remarked (1892) in reference to them: "it is somewhat doubtful whether they belong to the same species as the Victorian specimens, though from the examination of the external characters, which I have been permitted to make, I am inclined to believe that they do".

Spencer (1892) stated that he found four specimens in Tasmania, which he regarded as identical with the Victorian species. Three years later in recording the occurrence of *Peripatus insignis* in Tasmania he also remarked that at St. Clair, Dee Bridge and Parattah he found "considerable numbers of the land nemertine, *Geonemertes australiensis*".

Haswell (1914) and Steele (1926) have also mentioned the occurrence of the nemertine in this State but have given no further details.

Flynn (1928) remarked that a terrestrial nemertine, probably of another species, was by no means rare in gulleys of the lower slopes of Mount Wellington.

In view of the zoological interest in terrestrial nemertines and the little that has been recorded concerning their occurrence in Tasmania, it seems desirable to place on record some observations which I have made during the past 30 years as opportunity occurred.

In spite of its marked variations there appears to be only one species in Tasmania and there is no doubt that it is identical with *Geonemertes australiensis* Dendy. I have been able to compare Victorian and Tasmanian specimens and can find no justification for regarding them as different species. In the course of the present study over 200 specimens of the nemertine and many egg-capsules have been collected from different parts of the State.

On account of the work carried out by Dendy (1892) a detailed anatomical study is not required. However, special attention is given to variations

in colour, number of eyes, and proboscidial nerves, &c. The main features of the embryonic development are also described.

METHODS AND MATERIALS

Observations on colour and length were usually made on the living animal. For anatomical study the nemertine was narcotised in the vapour of chloroform and immediately placed in a fixative (Gilson's mixture, sublimate acetic or Bouin's picroformol). Sections were cut at 10μ and stained with Ehrlich's haematoxylin, eosin being sometimes used as a counter stain.

In order to obtain the eggs live specimens of the nemertine were kept in the laboratory. No difficulty was experienced in keeping them for six months or longer provided the temperature of the vivarium did not rise above 23° C. A temperature of 27° C. usually proved fatal. Hence during the summer, when there was any danger of high temperatures being reached, the specimens were transferred to a cool chamber. Each female was kept in a separate tin measuring about 10.0 cm. in diameter and 6.0 cm. in height. The tins contained moss, decaying leaves and rotten wood. The material was kept slightly moist and the tin closed with a lid. Collembolids were sometimes provided as food but usually sufficient small organisms were present amongst the moss and decaying leaves.

Gravid females collected in the field sometimes deposited their egg-capsules in two to four weeks after being placed in the tins. To ensure fertility male specimens were usually placed with the females. During summer many of the egg-capsules were destroyed by moulds. A similar destruction was also observed sometimes to occur in the field. However, in autumn and winter the eggs developed satisfactorily. The capsules were examined under the dissecting microscope each day during the course of incubation, hatching in the gelatinous matrix, and the emergence of the young from the capsules.

From time to time portions of the matrix containing eggs at different stages of development were taken, fixed in Bouin's fluid and sectioned. On other occasions the eggs were removed from the fixed material and sectioned separately. To avoid rendering the yolk of the eggs brittle the time in the embedding oven was made as short as possible, about 20 minutes.

In addition to the eggs laid by specimens in the laboratory others were obtained from capsules found in the field.

Young ones newly emerged from the capsules were placed on decaying leaves and rotten wood in small petri dishes, which were kept in the dark. The small nemertines readily caught collembolids offered as food.

OCCURRENCE AND DISTRIBUTION

In Tasmania *Geonemertes australiensis* usually occurs in cool and moist situations in shady gullies or on the margin of forest clearings. It is found under decaying logs, moss-covered stones, fallen leaves and the loose bark of dead trees. During the warm and dry periods of the year the nemertine often retreats into crevices of decaying logs or under deeply embedded stones. Large cream coloured specimens are generally found only in rain forest areas, whilst the darker reddish brown forms may be found in both rain forest areas and more open regions, such as the Trevallyn hills. Adult specimens may bo collected throughout the year.

As may be seen from Table 1 the nemertine is widely distributed in the State. In addition to the localities mentioned in the Table, it also occurs near the Great Lake and Lake St. Clair on the Central Plateau, at Anson's Bay on the East Coast and at Catamaran in the South. At Anson's Bay and Eaglehawk Neck it may be found almost at sea-level and sometimes within a short distance of the shore. However, it never occurs in the splash zone. If placed in sea water it reacts violently, everting its broboscis and failing to survive longer than about 30 minutes.

On some of the mountains it is found at considerable altitudes. Thus on Quamby Bluff, which has a height of 4200 ft., it occurs at the summit.

At no locality have I seen the nemertine in large numbers and it is a common experience to search areas, where it is known to occur, and yet not find a single specimen.

HABITS

In captivity *Geonemertes australiensis* does not move about very much. Specimens will remain in the one position for three or four days in succession apparently waiting for their prey. When at rest the nemertine is usually encased in a tough covering of mucus with only the front of its head exposed. The mucus coat extends forward for a short distance below and in front of the head forming a small area, which is covered with viscid slime secreted by the cephalic gland. If a small insect comes into contact with this area of sticky slime or if it merely touches against the body of the nemertine, the resting animal suddenly everts its proboscis in an attempt to capture the insect. Sometimes the prey is merely held by the adhesive papillae of the proboscis, but at other times the organ is coiled partly round the victim. The proboscis is extremely mobile and flexible. A small specimen of the nemertine was observed to evert its proboscis and bend it round in order to capture a collembolid, which was walking across the middle of its body. The captured insect was then drawn into the viscid slime in front of the head and the proboscis retracted. As the collembolid continued to struggle the proboscis was again fully everted and the insect pierced with the stylet. When the prey had ceased to move the rhynchostome was applied to it and the soft parts of its body sucked out, the skin and other hard parts being discarded.

Dendy (1892) has described the use of the proboscis as a means of locomotion but said that he was inclined to regard it as accidental and thought that the proboscis was normally used only as a weapon of offence or defence, probably for catching insects, but this he had not observed. From my own observations I am convinced that the proboscis is not only used in the capture of prey but is also normally employed as a means of sudden locomotion, when the nemertine endeavours to

TABLE 1

Localities at which specimens of *Geonemertes australiensis* were found and the numbers of males and females collected.

Date	Locality	Males	Females	Total
23 Dec. 1927	Wilmot	—	1	1
14 Apr. 1928	Trevallyn	—	1	1
20 Apr. 1929	Trevallyn	3	—	3
18 Apr. 1931	Trevallyn	2	2	4
28 May 1931	Trevallyn	—	3	3
27 Jun. 1931	Trevallyn	2	2	4
4 Jul. 1931	Trevallyn	2	1	3
11 May 1929	Glen Dhu	2	—	2
13 Nov. 1929	Glen Dhu	—	1	1
28 May 1930	Glen Dhu	1	1	2
12 Jul. 1930	Glen Dhu	4	8	12
19 May 1931	Glen Dhu	3	3	6
18 Jul. 1931	Glen Dhu	—	2	2
1 Aug. 1931	Glen Dhu	4	6	10
28 Aug. 1931	Exeter	1	2	3
8 Jul. 1957	Mt. Barrow	—	1	1
23 Feb. 1929	Liffey Falls	3	5	8
30 Mar. 1929	Liffey Falls	7	12	19
20 Sep. 1930	Quamby Bluff	1	3	4
22 Jan. 1931	Western Creek	4	3	7
23 May 1954	Surprise Valley	—	1	1
25 May 1954	Tarraleah	—	1	1
24 Dec. 1954	Tarraleah	4	2	6
29 Dec. 1954	Tarraleah	4	7	11
28 Mar. 1932	National Park	—	8	8
13 May 1928	Mt. Hobbs	1	5	6
29 Apr. 1939	Mt. Hobbs	—	1	1
4 Jan. 1929	Levendale	—	1	1
30 Nov. 1940	Eaglehawk Neck	1	—	1
22 Aug. 1951	Eaglehawk Neck	—	1	1
8 Mar. 1960	Eaglehawk Neck	—	3	3
12 Nov. 1957	Mt. Dromedary	1	—	1
4 Jan. 1934	Lenah Valley	—	1	1
1 Jun. 1948	Lenah Valley	2	2	4
16 Jul. 1948	Lenah Valley	—	2	2
6 Nov. 1956	Lenah Valley	2	1	3
15 Nov. 1956	Lenah Valley	—	4	4
27 Nov. 1956	Lenah Valley	4	3	7
12 Dec. 1956	Lenah Valley	2	1	3
22 Jan. 1957	Lenah Valley	1	4	5
28 Jan. 1957	Lenah Valley	—	1	1
28 May 1929	Cascades	1	1	2
29 Aug. 1930	Cascades	—	3	3
3 Sep. 1930	Cascades	2	4	6
1 Sep. 1931	Cascades	3	13	16
18 Nov. 1933	Cascades	1	1	2
18 Apr. 1961	Cascades	—	1	1
26 Oct. 1933	Fern Tree	—	1	1
18 Jan. 1962	Fern Tree	2	3	5
12 Apr. 1962	Fern Tree	1	1	2
4 May 1962	Fern Tree	1	1	2
7 May 1962	Fern Tree	1	—	1
5 Dec. 1955	Organ Pipes	1	—	1
22 Nov. 1955	Arve Forest	1	—	1
22 Nov. 1939	Hastings	—	1	1
Totals		75	136	211

escape from its enemies. Very small specimens, just emerged from the egg-capsule, will if irritated evert the proboscis, attach it to the substrate and quickly draw the body on to it. By repeating the process two or three times in succession a rapid forward movement is attained. Sometimes the proboscis is thrust into a crevice and the nemertine drawn in after it.

VARIATIONS

Length: Seventy-five sexually mature males varied in length from 12 mm. to 60 mm., and 136 sexually mature females varied from 12 mm. to 84 mm. In describing Victorian specimens Dendy (1892) stated that large ones when crawling reached a length of about 40 mm.

Colour and markings (Pl. 1, figs. 1-3): In both sexes the colour varies from pale cream, almost white, to dark reddish brown. The head region is generally darker and the ventral surface lighter than the rest of the body. In many cases the dark colour of the head is continued posteriorly as a median dorsal stripe, extending partly or entirely the full length of the animal. In reddish brown forms the colour is sometimes of a uniform shade; at other times it is dispersed in irregular blotches on a ground colour varying from cream to pale brown. Some specimens have the blotches arranged in longitudinal rows forming an incipient striped pattern, whilst others are marked with well-formed brown stripes. In the latter there is usually a median dorsal stripe with a single lateral stripe on each side. In other examples the median stripe is double, the animal thus having four longitudinal stripes. Striped and non-striped examples are sometimes found in the one habitat, and it is not unusual for egg-capsules to contain young ones with brown blotches and also young ones with little or no pigmentation.

Fletcher (1895) has recorded that some specimens found in Tasmania by Spencer were longitudinally striped with red. Dendy (1892) described the colour of Victorian specimens as being chiefly yellow, sometimes orange and at other times brownish. He also stated that some specimens had a brown median dorsal band and two narrow stripes of a darker brownish tint down each side.

Eyes: In young specimens that have recently hatched four eyes are usually visible (text-fig. 1). Two are situated one on each side of the front of the head, and the other two, which are slightly smaller, a short distance behind them. Before or shortly after the young have left the egg-capsule further small eyes appear in proximity to the primary four (text-fig. 2). It thus happens that the eyes tend to be arranged in four groups, right and left anterior and right and left posterior. In Table 2 these groups are indicated by the letters RA, LA, RP and LP respectively. By the time the nemertine has grown to a length of 5 mm. it usually has about 16 eyes, four in each group (text-fig. 3). In adult specimens the total number of eyes varies from about 39 to 176. Usually the number is greater in large than in small specimens, but this is not always the case (Table 2). However, the great powers of extension and contraction of the nemertine and the fact that the length of a female decreases considerably after the eggs are laid make it difficult to obtain measurements of length that are strictly comparable.

In some specimens the anterior and posterior groups on each side merge so that the animal appears to have only one large group on each side.

Dendy (1892) stated in reference to Victorian specimens that the eyes, of which there might be as many as thirty or forty, were arranged in two groups, one on either side of the opening of the rhynchodaeum at the anterior extremity of the body. Each group, containing about twenty eyes of various sizes, might show indications of a division into an anterior and posterior portion.

In a Victorian specimen which I examined there were 79 eyes arranged in four irregular groups corresponding in position to the four primary eyes of the newly hatched young (text-fig. 4). This is the arrangement found in most Tasmanian specimens (text-fig. 5). Some of the eyes in young specimens appear to be formed by division of the primary eyes. Others seem to arise independently.

Vascular system: Anteriorly the median blood vessel ends in two cellular plugs, which project into the rhyncocoelom immediately above the ventral commissure of the brain. In reference to these structures in a Victorian specimen Dendy (1892) remarked that the median vessel seemed to be connected with both these cellular plugs and that it appeared to be directly continuous with the stalk of the one and to send off a branch to the other. Whether there was any constant distinction between the right and the left in this respect he was not able to say.

In Tasmanian specimens the median blood vessel divides dichotomously at its anterior end forming two symmetrical short branches, one on each side leading to the corresponding vascular plug. There is no indication of the median vessel being directly continuous with the stalk of one of the plugs rather than the other.

Proboscidial nerves (Pl. 2, figs. 7-12): The proboscidial nerve sheath is thickened at regular intervals to form a number of longitudinal nerves. Dendy (1892) did not state the number in the Victorian specimen which he described, but the figure he gave shows eighteen. Darbishire (1909), who examined twelve specimens given to him by Dendy, stated that two of the specimens had 16 nerves, two 17, seven 18 and one 19. He therefore concluded that the specimen, whose proboscis was figured by Dendy, represented the commonest type.

In order to determine the range of variability in the number of proboscidial nerves in Tasmanian examples of the nemertine, 187 adult specimens collected in the field and 374 young ones bred from three egg-capsules were examined. The results are shown in Tables 3 and 4.

The specimens obtained from the three egg-capsules were ones that had recently emerged from the gelatinous matrix. Their gonads had not developed and it was not possible to determine their sex.

From the data given in Tables 3 and 4 it is apparent that the number of longitudinal proboscidial nerves may vary from 11 to 21 and that 14 represents the number most frequently met with. It is also clear that both males and females show much the same range of variability.

TABLE 2

Number of eyes in 10 males and 10 females of *Geonemertes australiensis*.

Length of specimen in mm.	Sex	RA group	Number of eyes			Total
			LA group	RP group	LP group	
12	♂	15	15	9	9	48
15	♂	16	20	11	11	58
20	♂	11	11	9	8	39
25	♂	16	14	11	9	50
35	♂	18	15	15	14	62
35	♂	18	21	19	17	75
35	♂	41	41	35	37	154
35	♂	18	23	22	26	89
40	♂	23	23	21	23	90
47	♂	14	18	13	11	56
10	♀	15	13	9	9	46
15	♀	15	16	8	6	45
20	♀	43	42	37	36	158
30	♀	24	23	19	16	82
36	♀	38	24	22	22	106
42	♀	28	24	26	23	101
51	♀	36	36	55	49	176
59	♀	32	32	49	51	164
70	♀	22	19	20	14	75
81	♀	28	33	27	32	120

TABLE 3

Number of longitudinal proboscidial nerves in 187 adult specimens of *Geonemertes australiensis*.

Number of proboscidial nerves	Number of specimens		
	Males	Females	Total
11	—	1	1
12	1	4	5
13	4	11	15
14	43	65	108
15	8	20	28
16	8	17	25
17	2	1	3
18	1	—	1
21	1	—	1
TOTALS	68	119	187

Reserve stylet-sacs: In young specimens newly emerged from the egg-capsule there are two reserve stylet-sacs, one on each side of the proboscis. Each sac contains two or sometimes three stylets. In adult specimens the number of sacs varies from two to eleven (Table 5). The most usual number is five, three on one side and two on the other. The number of stylets contained in a sac varies from one to five (Pl. 1, fig. 6).

Dendy (1892) remarked that in one of his specimens he counted as many as five stylet-sacs. In a Victorian specimen which I examined there were definitely eight sacs and perhaps ten, two being indistinct. Dendy did not succeed in finding any communication between the reserve sacs and the lumen of the eversible part of the proboscis, but assumed that some communication existed. In many of my specimens the communication is quite distinct.

TABLE 4

Number of longitudinal proboscidial nerves in 374 young specimens of *Geonemertes australiensis* bred from three egg-capsules.

Number of proboscidial nerves	Number of specimens			
	Capsule 1	Capsule 2	Capsule 3	Total
12	1	1	1	3
13	—	2	2	4
14	73	44	45	162
15	3	68	34	105
16	4	52	26	82
17	—	7	5	12
18	—	2	3	5
19	—	—	1	1
TOTALS	81	176	117	374

TABLE 5

Number of reserve stylet-sacs in 66 specimens of *Geonemertes australiensis*.

Number of stylet sacs	Number of specimens		
	Males	Females	Total
2	2	3	5
3	4	2	6
4	3	14	17
5	8	12	20
6	6	4	10
7	3	—	3
8	2	—	2
9	—	2	2
11	—	1	1
TOTALS	28	38	66

EGG-LAYING AND INCUBATION

A brief description of the gelatinous egg-capsule of *Geonemertes australiensis* has been given by Dendy (1893). However, his assumption that the animal discharged its eggs and poured out the jelly, while slowly crawling along, is not correct. The nemertine remains stationary while depositing its eggs. A specimen collected at Trevallyn on 14th April, 1928, and kept in the laboratory was observed in the act of egg-laying on 18th May, 1928. With the exception of the head the body of the worm was encased in a smooth elastic coat of tough mucus, which did not appear to differ from that normally surrounding the body of the resting animal. When first noticed at 3.30 p.m. a number of eggs on each side of the body had already been discharged and were lying in gelatinous material between the mucus coat and the surface of the body. As the eggs were discharged from the ovigerous sacs movements of the musculature occurred forcing the eggs through the narrow ducts leading to the surface. At the place where each egg had been expelled a small lesion appeared, no doubt due to the rupture of the narrow opening through which the egg had passed. The laying of the eggs was observed under a dissecting microscope until 4.10 p.m., when the nemertine was photographed while further eggs were being discharged (Pl. 1, fig. 4). By 6 p.m. the worm had crawled out of the surrounding mucus coat leaving the eggs suspended in the gelatinous matrix. The elastic nature of the mucus coat causes it to close at the ends, when the body of the nemertine has been withdrawn.

The egg-capsules thus made are generally spindle-shaped or sausage-shaped (Pl. 1, fig. 5) and vary in size from 8 mm. x 4 mm. to 48 mm. x 10 mm. The small egg-capsules may contain only four eggs, whereas the largest may hold several hundred. One measuring 15 mm. x 4 mm. contained 87 eggs, while one 23 mm. x 7 mm. contained 290.

It is not unusual for the nemertine to make several egg-capsules at short intervals. Dendy (1893) has recorded one of his specimens as depositing three lots of eggs between 7th July and 1st August. A large specimen, which I collected at the Fern Tree on 19th January, 1962, and kept in the laboratory, deposited seven egg-capsules between 6th April and 23rd May. When found the nemertine measured 84 mm. long and 5 mm. wide, but after depositing the seventh lot of eggs it measured only 50 mm. long and 2 mm. wide.

A specimen which was disturbed when about to lay its eggs made a complete egg-capsule (20 mm. x 7 mm.) filled with the usual gelatinous material but without eggs.

In the field egg-capsules are deposited under logs, stones, fallen leaves, moss, &c., in cool and moist situations. In rain forest areas they may be found throughout the year, but in more open localities, such as the Trevallyn hills, they are deposited only during the autumn and winter. The transparency of the egg-capsule makes it possible to examine the eggs and embryos in the living condition and to recognise some of the stages of development in capsules found in the field (Table 6).

TABLE 6

Stages of development of eggs or young in capsules of *Geonemertes australiensis* found in the field.

Date	Locality	Number of capsules	Stage of development of eggs or young.
9 Jun., 1928	Trevallyn	1	Early cleavage
18 Aug., 1928	Trevallyn	5	Young moving in matrix
23 Feb., 1929	Liffey Falls	2	Young with four eyes
21 Mar., 1933	Cascades	1	Near hatching
29 Dec., 1954	Tarraleah	3	Young moving in matrix
11 Nov., 1955	Arve Forest	2	Late segmentation
10 Jan., 1962	Fern Tree	1	Hatching in matrix
12 Apr., 1962	Fern Tree	1	Late segmentation
7 May, 1962	Fern Tree	1	Near hatching
18 Jul., 1962	Fern Tree	1	Near hatching

The period of incubation is relatively short and varies even amongst the eggs in the one capsule. On 6th May, 1962, a capsule measuring 12 mm. x 5 mm. and containing about 120 eggs was deposited by a specimen kept in the laboratory. The eggs were examined under the dissecting microscope each day until they hatched in the gelatinous matrix. The daily observations were then continued until the young left the capsule. During the period the ambient temperature fluctuated betwen 10° C and 16° C with an average daily temperature of 13° C. Most of the eggs hatched in the gelatinous matrix in 15 to 16 days, but some took 19 days. The newly hatched young remained in the capsule for another 24 days. The period of incubation and rate of development within the egg-capsule are shown in Table 7.

TABLE 7

Rate of development of the eggs of *Geonemertes australiensis* in a capsule deposited in the vivarium.

Date	Stage of development
6 May, 1962	Eggs laid
7 May, 1962	Most embryos at four cell stage
8 May, 1962	Morula
12 May, 1962	Embryos at late segmentation stage
21 May, 1962	Some embryos hatching in gelatinous matrix
23 May, 1962	Young measure 0.63 mm. long
25 May, 1962	Young moving about in gelatinous matrix
27 May, 1962	Two anterior eyes visible in some young
29 May, 1962	Young measure 1.08 mm. long
1 Jun., 1962	Young more active. Some with four eyes
2 Jun., 1962	Head region darkening
5 Jun., 1962	Young measure 1.26 mm. long
8 Jun., 1962	Faint brownish blotching on body of some young
10 Jun., 1962	Young congregating at upper end of capsule
14 Jun., 1962	Young measure 1.83 mm. long. Leaving capsule

Dendy (1893) has recorded that he examined on the 26th August embryos in a mass of eggs, which had been deposited on 1st August and found that some of the embryos were still enclosed in the delicate egg-membrane, whilst others had hatched and were moving about in the gelatinous matrix.

EMBRYONIC DEVELOPMENT

(Text-figs. 6-20)

The newly laid egg is spherical and has a diameter of 0.63 mm. to 0.74 mm. It is white or pale yellow, opaque, laden with yolk granules and surrounded by a delicate investment. The nucleus is slightly excentric in position and without a well defined nuclear membrane.

In the early stages of development segmentation is holoblastic and equal (text-figs. 6-9). The first cleavage usually occurs about 12 hours after the egg is laid. The two blastomeres so formed are loosely held together and readily fall apart, when the egg is removed from the gelatinous matrix. At the end of 24 hours most of the eggs in a capsule have undergone the second cleavage and reached the four cell stage.

Further cleavages are of the spiral type and give rise to a typical morula followed by a hollow blastula. The wall of the blastula consists of a single layer of wedge-shaped cells (text-fig. 10). As segmentation proceeds the blastomeres become long and narrow (text-fig. 11).

On or shortly after the fourth day of incubation gastrulation occurs. Cells at the vegetative pole enter the blastocoel by a process of ingression and constitute the endoderm. A small temporary depression appears on the surface of the embryo at the place where the cells are moving inward but there is no marked invagination (text-fig. 12.)

While gastrulation is taking place other cells are separating off from the inner portions of the elongate blastomeres forming the wall of the blastula. These cells surround the endoderm and appear to constitute mesectoderm. The outer ends of the elongate blastomeres remain unchanged until a late stage. They have the form of large cells, which are full of yolk and bulge on the surface making the embryo appear as if it were still in the stage of an advanced morula. These outer cells, which surround the embryo, will be referred to as *ectoembryonic* cells.

By the end of th seventh day the blastocoel is completely filled with a mass of cells and its lumen obliterated (text-fig. 13). The large ectoembryonic cells have nuclei, which measure about 18 μ in long diameter, whereas those forming the inner mass have nuclei measuring only 6 μ in diameter.

The next stage in development is marked by a proliferation of the mesectoderm cells, which form the outer zone of the inner cell mass and lie immediately below the ectoembryonic cells. A dense group of cells formed in the mesectoderm at the anterior end of the inner cell mass gives rise to the rhynchodaeum, proboscis and brain. The rhynchodaeum and proboscis develop as an invagination of the cells immediately below the anterior ectoembryonic cells (text-figs. 14 and 15). The ectoembryonic cells are still laden with much yolk and do not take part in the invagination. Their large nuclei seem to disintegrate and the main function of these cells appears to be the supplying of nourishment in the form of yolk to the actively dividing cells below them. At this stage they also close the entrance to the rhynchodaeum.

The right and left lobes of the brain first appear as groups of ganglion cells on either side of the invagination forming the proboscis (text-figs 15 and 16). At the same time the lateral nerves are formed as two longitudinal ridges in the mesectoderm on each side and immediately below the large ectoembryonic cells (text-figs. 17). The two ridges extend from the brain to the posterior end of the inner cell mass, where they unite.

Some cells of the proliferating mesectoderm now become differentiated to form the dermal muscular sheath, whilst other cells grow out and invade

ths large yolky ectoembryonic cells using up the yolk and forming here and there patches of ciliated epithelium (epidermis). The embryo now rotates within the delicate egg-membrane.

By this time the endodermal part of the inner cell mass consisting mainly of large blocks of yolk granules with a few scattered nuclei, has become delimited to form the primitive gut. In some cases a small cavity appears in the centre of the mass.

The embryo is now about eleven days old and shows signs of muscular movement. The proboscis has grown back for about half the length of the body and is surrounded by the wall of the rhynchocoelom, which has been formed by delamination from the developing proboscis. Below the proboscis and growing inwards from the rhynchodaeum the oesophagus is being differentiated (text-figs. 14 and 16).

During the next few days the embryo elongates. The posterior half of the rhynchocoelom together with the rudiments of the retractor muscle of the proboscis develop. The ectoembryonic cells become replaced entirely by the ciliated epidermis, which has formed in patches but now covers the whole embryo.

On or about the fifteenth day of incubation the young nemertine escapes from the delicate investing egg-membrane and moves into the gelatinous material of the egg-capsule. In some cases hatching occupies several hours. The membranous investment does not appear to be torn or burst open but to have a narrow rounded hole formed in it. Through this hole the nemertine slowly squeezes its body and when about half-way through it appears constricted in the middle or dumb-bell shaped. When moving in the gelatinous matrix and fully extended it measures about 1.0 mm. in length, but is still in a very immature condition (text-fig. 18). The rhynchostome is closed and the stylet region of the proboscis not fully developed. The gut is full of yolk and its endothelium not formed. The blood vascular system is not apparent and numerous yolk granules are present in various regions of the body. In most cases the eyes are not evident, but in some the two main anterior eyes may be seen.

As mentioned previously the young nemertine remains in the egg-capsule for a further 24 days or longer. During this period it grows to a length of from 2.0 to 3.0 mm., and on leaving the egg-capsule its main organs, excepting the gonads, are formed.

The head is dark and the dorsal surface and sides of the body faintly blotched with brown. In many cases the blotching tends to form stripes. However, some specimens show very little pigmentation. Four eyes are usually present and sometimes eight or nine. The rhynchostome is open to the exterior. The longitudinal nerves of the proboscis are already established in number (text-fig. 19), and the stylet region well developed. The main stylet is about 36 μ in length, while the pyriform base on which it is mounted measures about 50 μ in length and 30 μ in greatest width. Two reserve stylet sacs are present, one on each side (text-fig. 20). They contain two and sometimes three stylets. The proboscis can be everted and withdrawn as in the adult.

The lobes of the brain, dorsal and ventral commissures, the lateral nerves and accessory lateral nerves are all well formed. The ciliated ducts or cephalic pits leading to the ganglia of the lateral organs are open to the exterior. The head gland, dorsal and epidermal glands are established.

The blood vascular system resembles that of the adult. The median vessel bifurcates at its anterior end to form two short branches, which lead to the vascular plugs in the wall of the rhynchocoelom. Here and there in the parenchyma tubules of the nephridial system may be seen.

In the alimentary canal the wall of the oesophagus is now folded and its endothelial lining ciliated. The intestine, however, still contains much yolk, and the large yolky endoderm cells have not yet formed the endothelium of the gut.

DISCUSSION

The egg-capsules of *Geonemertes australiensis* resemble those of *Geonemertes dendyi* Dakin as illustrated by Pantin (1961), but in mose cases are of larger size.

Coe (1939) has suggested that occasional viviparity may possibly occur in some species thought to be exclusively oviparous. No cases of viviparity, protandry or hermaphroditism were observed among the specimens of *G. australiensis* examined during the present investigation.

Little appears to have been recorded concerning the embryology of terrestrial nemertines. Coe (1904) has given a brief account of the development of the viviparous species, *Geonemertes agricola* (Willimoes-Suhm), which occurs in Bermuda. Dendy (1893) states that he had little success in investigating the development of *G. australiensis*, since the large quantity of food yolk made the living embryos opaque and moreover the cutting of sections did not yield satisfactory results. It is true that the yolk is an obstacle to the examination of the living embryos. It also tends to become brittle after fixation and embedding, thus making the cutting of sections difficult. However, the difficulty may be overcome to some extent by reducing the times of fixation and embedding to a minimum.

From my own observations the development of *G. australiensis* bears some resemblance to that of *Prostoma graecense* (Böhmig) as recorded by Reinhard (1941). In both nemertines gastrulation takes place by a process of ingression of cells at the vegetal pole. However, the formation of the mesoderm differs in the two species.

The large ectoembryonic cells of *G. australiensis* are not unlike the large outer cells of the newly hatched larva of *Oerstedia dorsalis* (Abildgaard) as figured by Coe (1943). In the latter case, however, they appear to give rise directly to the epidermis of the adult, whereas in *G. australiensis* they seem to degenerate and merely provide yolk for the proliferating cells below them. In describing the development of *G. agricola* Coe (1904) has stated that "it is not quite certain that the ciliated covering of the young embryo is actually converted

into the ciliated integument of the adult worm". He thought that it might be sloughed off. The ectoembryonic cells of the embryo of *G. australiensis* are not ciliated and are not cast off. However they do not appear to give rise to the integument of the adult.

Development of *G. australiensis* is direct and the mode of formation of the various organs resembles that found in other Metanemertini.

ACKNOWLEDGMENTS

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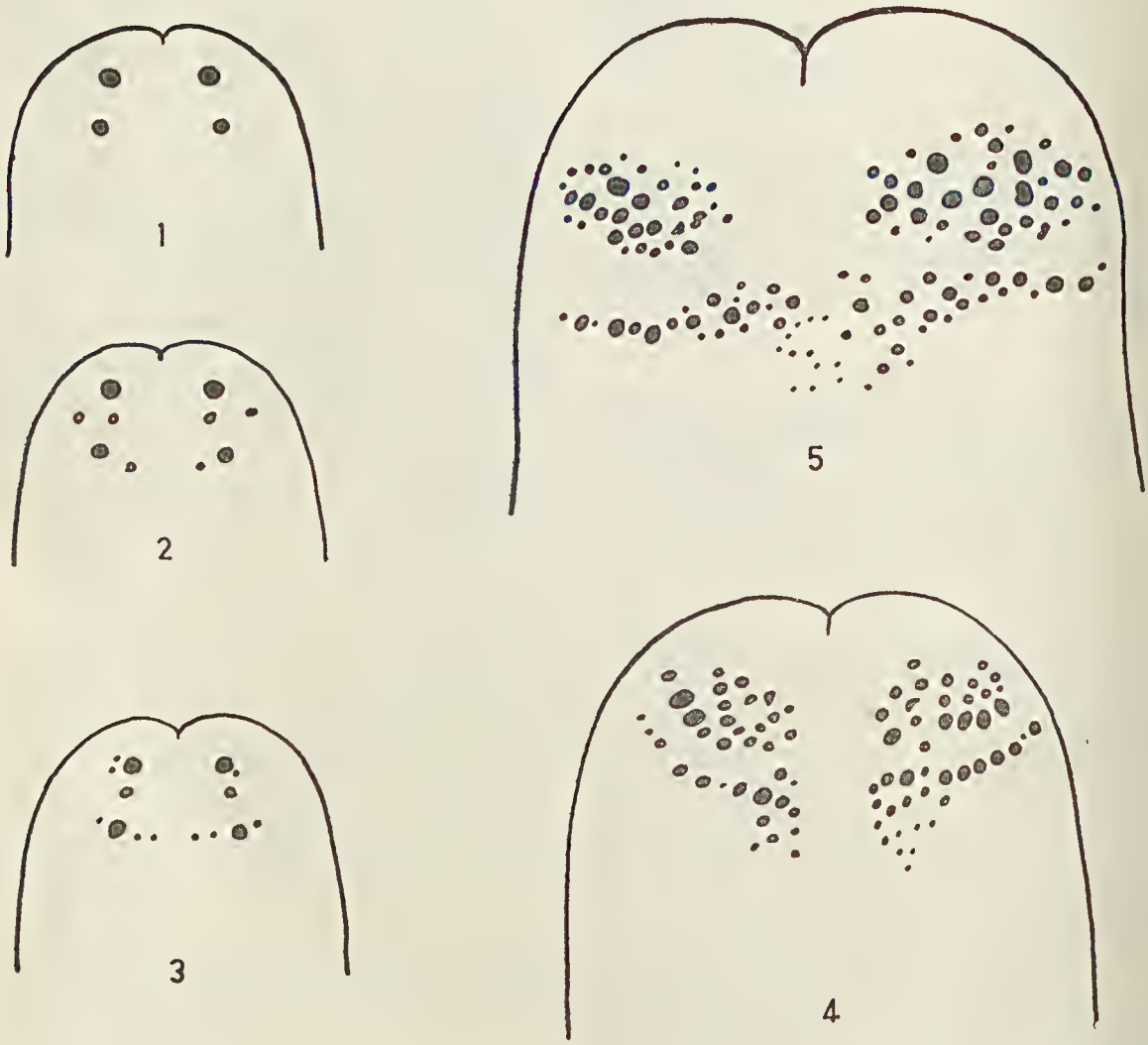
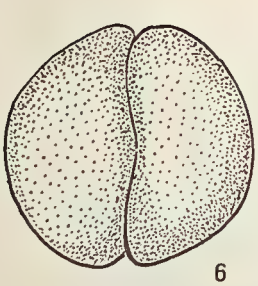


GEONEMERTES AUSTRALIENSIS DENDY

FIG. 1.—Eyes in a recently hatched specimen about 2.0 mm. long.
FIG. 2,—Eyes in a specimen about 3.6 mm. long.
FIG. 3.—Eyes in a specimen about 5.0 mm. long.
FIG. 4.—Eyes in a specimen from Victoria.
FIG. 5.—Eyes in an adult specimen from Tasmania.



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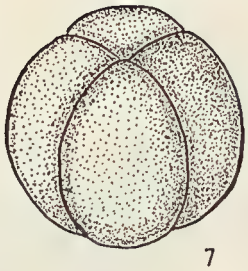

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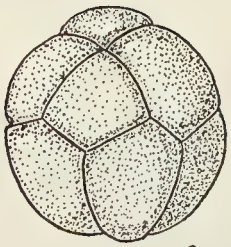

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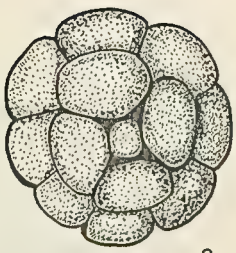

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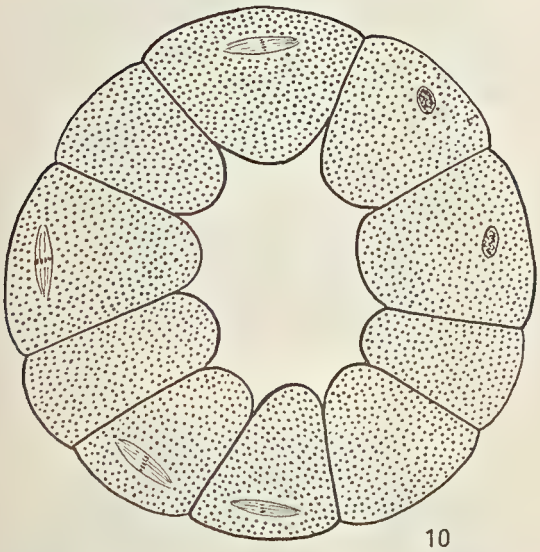

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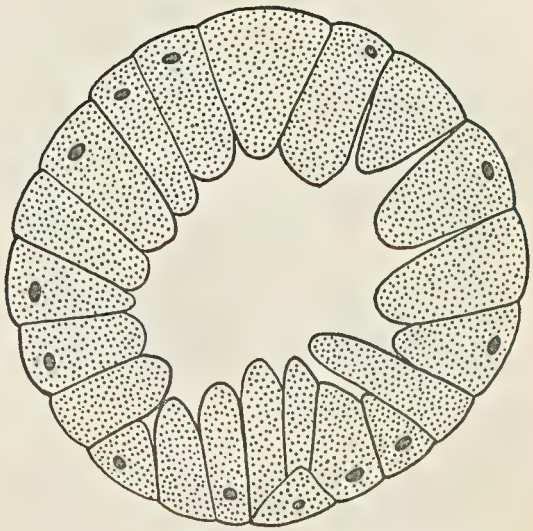

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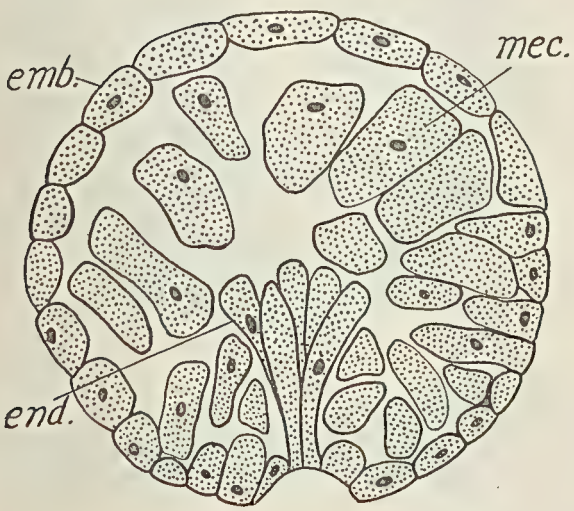

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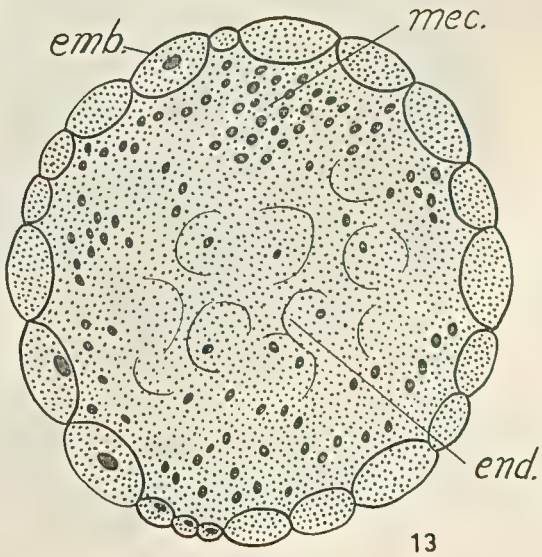

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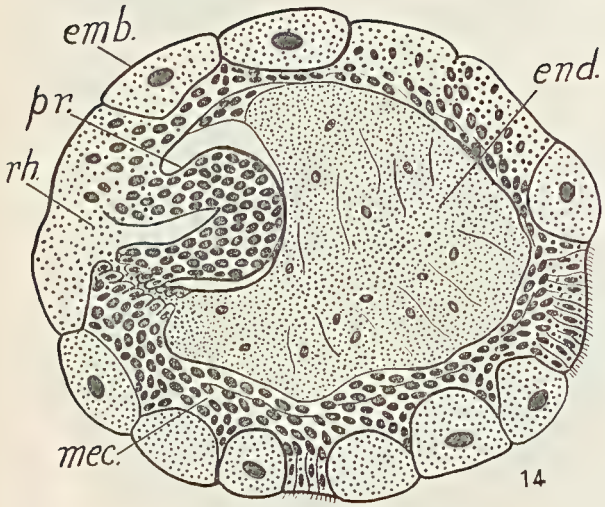
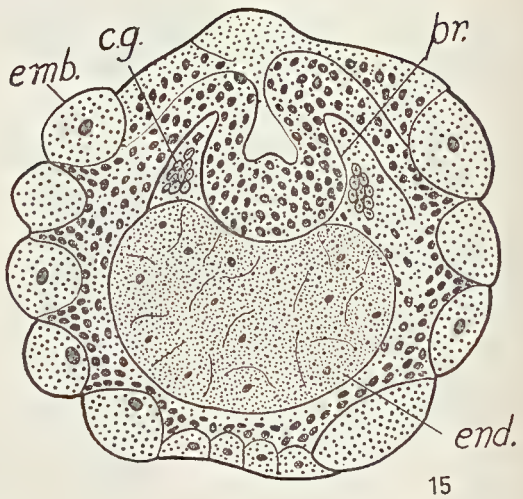
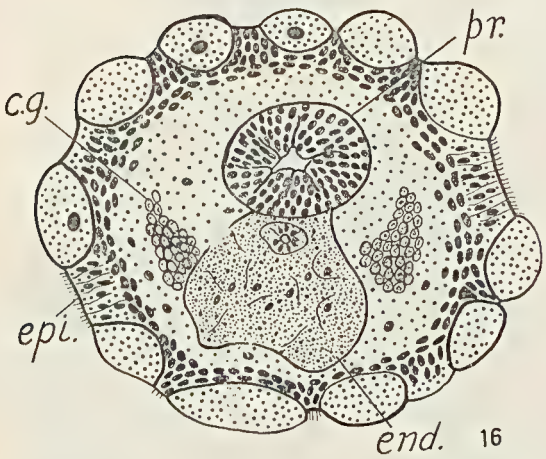
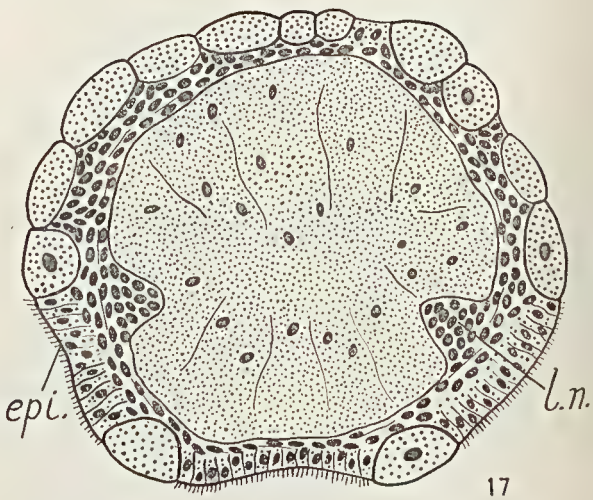
GEONEMERTES AUSTRALIENSIS DENDY

Fig. 6.—Two cell stage.
Fig. 7.—Four cell stage.
Fig. 8.—Eight cell stage.
Fig. 9.—Morula.
Fig. 10.—Section through early blastula.
Fig. 11.—Section through a more advanced blastula.
Fig. 12.—Section through gastrula showing ingression of cells at vegetal pole. *end.* endoderm, *emb.* ectoembryonic cells, *mec,* mesectoderm.
Fig. 13.—Section through a later stage showing inner mass of cells filling the blastocoel. Lettering as in Fig. 12.



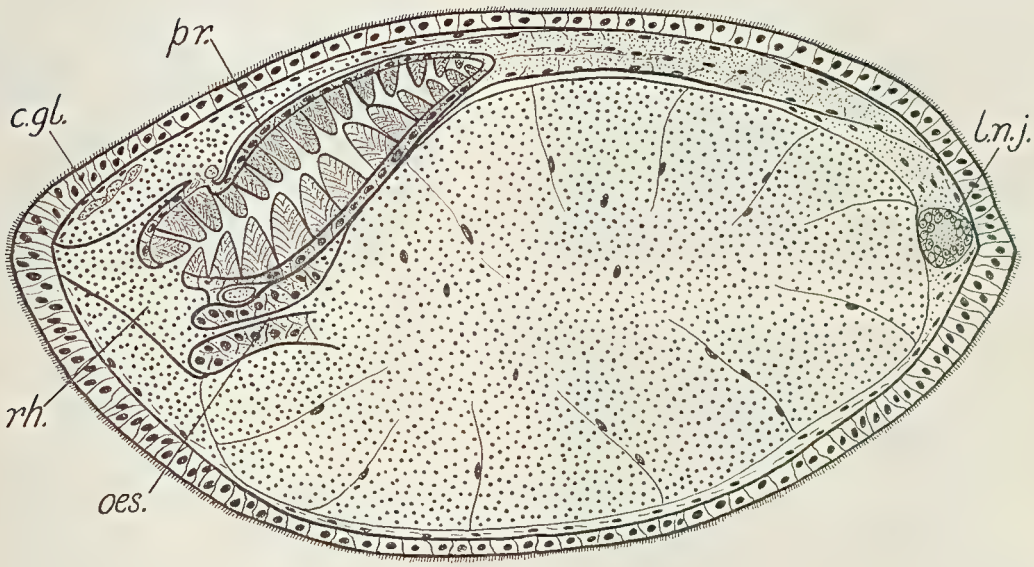






GEONEMERTES AUSTRALIENSIS DENDY

FIG. 14.—Sagittal section through an embryo about 10 days old.
FIG. 15.—Frontal section through an embryo of about the same age.
FIG. 16.—Transverse section through an embryo about 10 days old and passing through the proboscis.
FIG. 17.—Transverse section through an embryo of about the same age but passing behind the proboscis. *c.g.* cerebral ganglion, *emb.* ectoembryonic cells, *end.*, *endoderm*, *epi*, epidermis, *l.n.*, lateral nerve, *mec.* mesectoderm, *pr.* proboscis, *rh.* rhynchodaeum.



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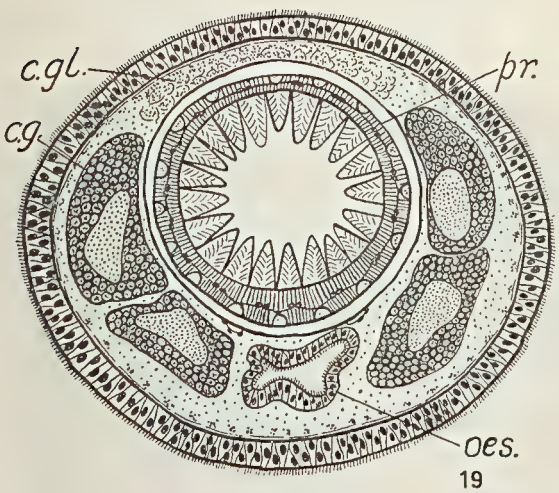

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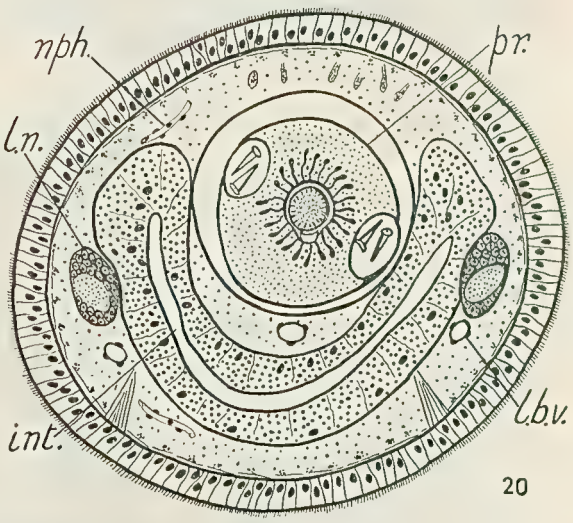

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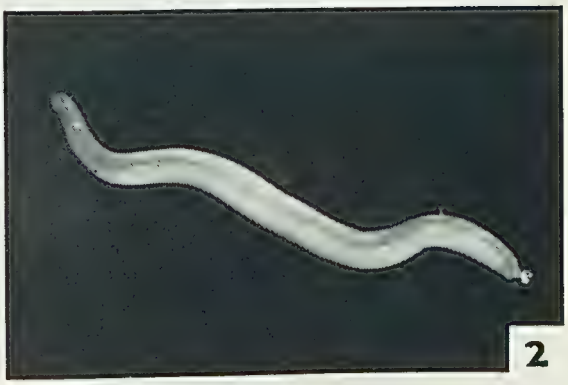
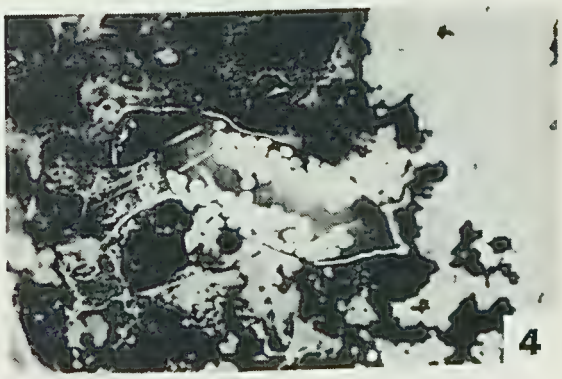
GEONEMERTES AUSTRALIENSIS DENDY

FIG. 18. Sagittal section through a newly hatched specimen.
FIG. 19.—Transverse section at the level of the brain through a specimen recently emerged from the egg-capsule.
FIG. 20.—Transverse section through the middle of the body of a specimen recently emerged from the egg-capsule. The section passes through the stylet region of the proboscis. *c.g.*, cerebral ganglion (brain), *c.gl.* head gland, *int.* intestine, *l.b.v.* lateral blood vessel, *l.n.* lateral nerve, *l.n.j.* junction of lateral nerves, *nph.* nephridial tubule, *oes.* oesophagus, *pr.* proboscis.





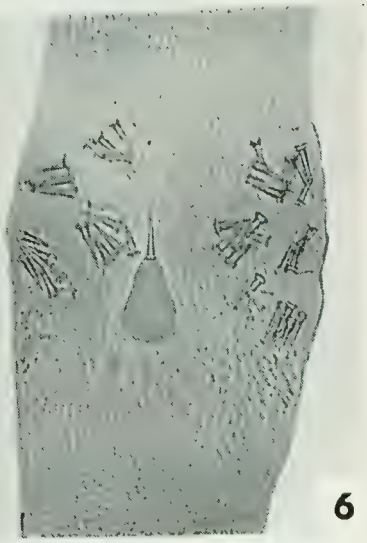


PLATE 1

Geonemertes australiensis Dendy

FIG. 1.—Pale cream specimen resting on piece of charred wood.
FIG. 2.—Cream specimen showing a median dorsal stripe.
FIG. 3.—Light brown specimen with dark brown stripes.
FIG. 4.—A brownish specimen laying eggs.
FIG. 5.—Egg-capsules.
FIG. 6.—Stylet region of proboscis compressed and showing ten groups of reserve stylets, each group being in a separate sac.

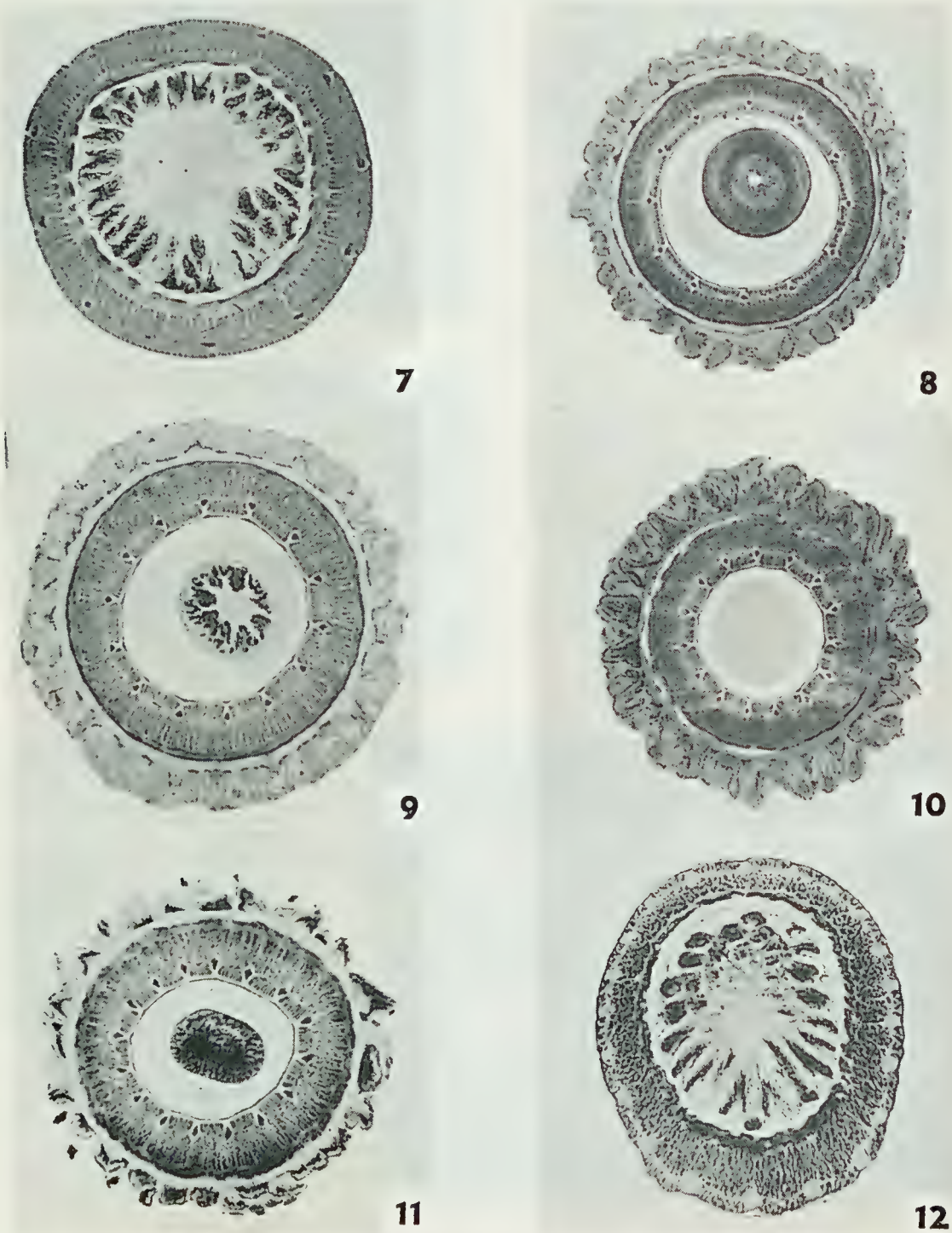


PLATE 2

Geonemertes australiensis Dendy

Figs. 7-12.—Transverse sections of proboscides showing 11, 12, 14, 15, 16 and 21 nerves respectively. In Figs. 7 and 12 the proboscis is withdrawn; in the other figures it is everted.

A NEW SPECIES OF ECHINODILLO (ISOPODA, ONISCOIDEA, ARMADILLIDAE) FROM FLINDERS ISLAND, TASMANIA

By

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ABSTRACT.

Examples of a new species of Armadillidae, found on Flinders Is., show striking similarities to *Echinodillo montanum* Jackson, the type species of *Echinodillo* Jackson, but in some respects they do not comply with the original diagnosis of this genus. After consideration of the differences, this diagnosis is emended to cover the new species. A detailed description of the species *E. cavaticus*, is given.

Genus **ECHINODILLO** Jackson, **nom. emend.**

Echinodillo Jackson, 1933, p. 159.

Type Species, *Echinodillo montanum* Jackson, 1933, p. 159, figs. 4, 5.

Jackson (1933, p. 159) established *Echinodillo* for one species, *E. montanum*, from Uahuka, Marquesas Is. I have examples of a new species from Flinders Is., in the Furneaux Group (situated to the north of Tasmania), which I consider to be congeneric with *E. montanum*, as it has significant characters in common with the latter. However some characters of the Flinders Is. species conflict with Jackson's generic diagnosis of *Echinodillo;* these differences are as follows:—

(1) Jackson specified the presence of 3 spines on the posterior border of the cephalon and each segment of the pereion, and one median spine on each of the 3rd-5th segments of the pleon. In the Flinders Is. species the numbers of spines on the corresponding structures are 6 and 2 respectively, and not all of the spines on the segments of the pereion are situated along the posterior borders.

(2) Jackson described the terminal segment as having its posterior border drawn out into a long median spine. In the Flinders Is. species this median spine is short relative to the rest of the terminal segment.

I consider these differences to be of not more than specific value. There is striking similarity between the two species in the occurrence and form of the spines on the dorsal surface, epimera and pleura, and in the form of the terminal segment. In the knowledge of this similarity, Jackson's limits on the exact number and position of the dorsal spines and the relative length of the spine on the terminal segment, based as they are on the one species known at the time, appear unduly narrow. The presence of spines on the dorsal surface of the cephalon and all segments except the 1st and 2nd segments of the pleon, and the unusual form of the epimera, pleura and terminal segment, together with the form of the outer border of the 1st segment and the articulating lobes of the 1st and 2nd segments of the pereion, should be sufficient to characterize the genus.

One statement in Jackson's diagnosis is misleading. He noted that all of the free segments except the first of the pereion and the pleon are drawn out laterally into long recurved spines. Later, in his specific description of *E. montanum*, he (p. 159) stated that the 1st segment of the pleon is hidden under the 7th segment of the pereion. Thus in *E. montanum*, as in the Flinders Is. species, it is the 1st segment of the pereion and the 1st and 2nd segments of the pleon which are not drawn out laterally into long recurved spines; this is confirmed by Jackson's drawings (figs. 4*a*, 5*f*).

In the knowledge of the characters of this new species, I propose the following diagnosis of *Echinodillo*, which is emended from that given by Jackson (1933, p. 159) in the matters just discussed.

Generic diagnosis.

Frontal shield raised prominently from vertex, slightly produced in median line of margin. Side-plates of all segments, except 1st segment of pereion and 1st and 2nd segments of pleon, drawn out laterally into long recurved spines; anterior and posterior lateral angles absent. Cephalon and each segment of pereion with long, recurved, dorsal spines; fewer spines on each of 3rd-5th segments of pleon. Terminal segment coarctate, narrow; its posterior border drawn out into a median spine. Border of 1st segment of pereion thin and concave, not split; small articulating lappets placed well back from border of 1st and 2nd segments of pereion.

The wide geographic separation of the two known species of *Echinodillo* can probably be explained by the fact that knowledge of the oniscoid fauna of the Australian region is still far from complete, so that related, but as yet unrecorded, species may well exist in intervening places.

Key to species of the genus Echinodillo.

Number of dorsal spines 3 on cephalon and on each segment of pereion, one on each of 3rd-5th segments of pleon; protopodite of uropod not terminating in a spine .... *E. montanum.*

Number of dorsal spines 6 on cephalon and on each segment of pereion, 2 on each of 3rd-5th segments of pleon; protopodite of uropod terminating in a spine .... *E. cavaticus*, n. sp.

Echinodillo cavaticus, n. sp.

(Figs. 1-12).

Location of type specimens.—Holotype male and allotype female in the Australian Museum, Sydney. Paratype male and female in the Western Australian Museum, Perth. Paratype male and female in the Department of Zoology, University of Tasmania, Hobart.

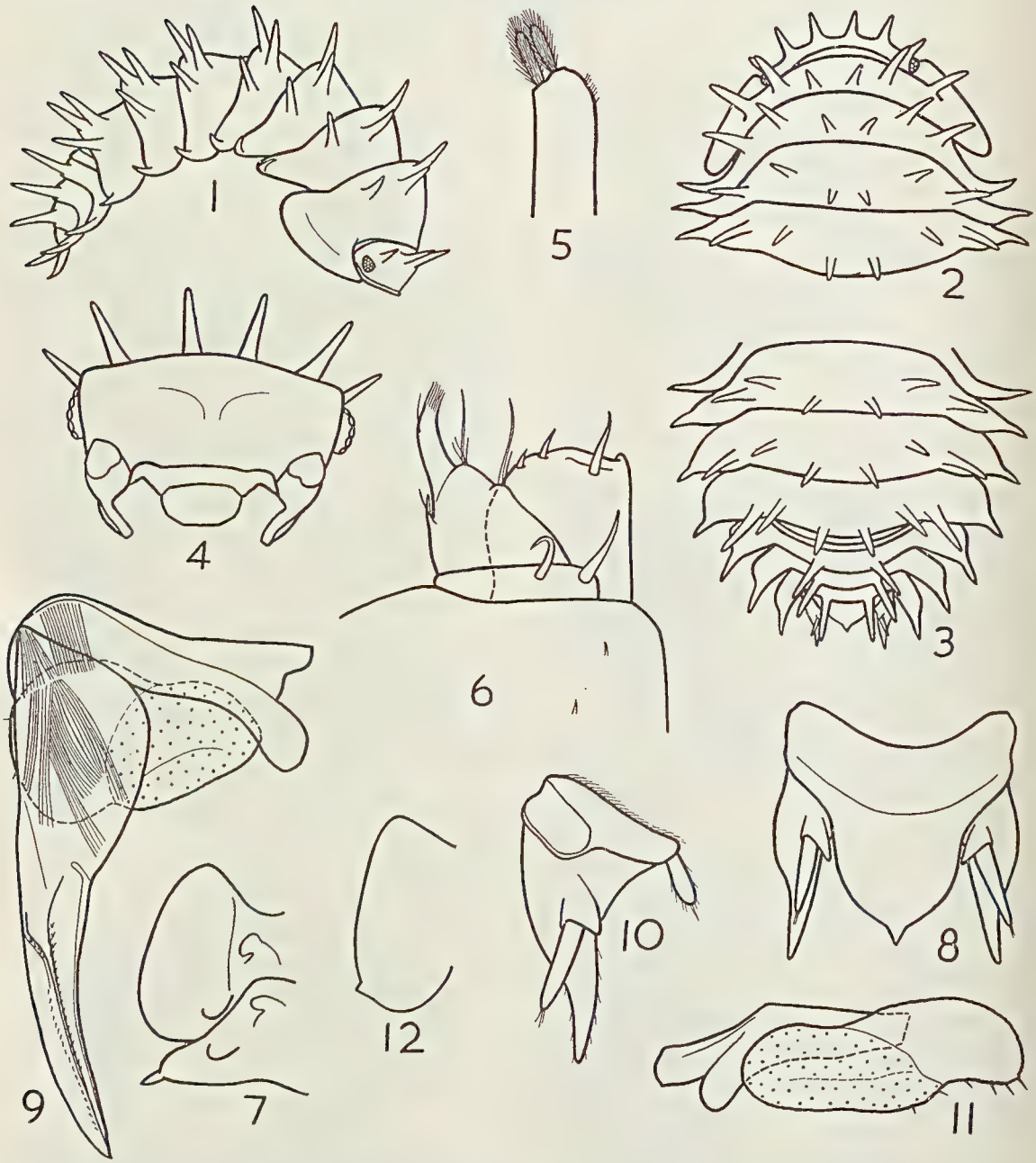

FIG. 1.—Cephalon, pereion and pleon, from right side. (Spines of left side, and appendages, have been omitted.)
FIG. 2.—Cephalon, and 1st-4th segments of pereion, dorsal view.
FIG. 3.—5th-7th segments of pereion, pleon and uropods, dorsal view.
FIG. 4.—Cephalon, anterior view. (Antennae and mouthparts removed.)
FIG. 5.—Distal part of inner lobe of left 1st maxilla, ventral view.
FIG. 6.—Distal part of right maxilliped, ventral view.
FIG. 7.—Right epimera of 1st and 2nd segments of pereion, ventro-lateral view.
FIG. 8.—Terminal segment and uropods, dorsal view.
FIG. 9.—Right 1st pleopod of male, dorsal view.
FIG. 10.—Left uropod, dorsal view.
FIG. 11.—Right 1st pleopod of female, ventral view.
FIG. 12.—Left 1st epimeron of a female, showing pointed projection on outer border, dorsal view.

MALE.

Size.—Length of largest specimen 6.8 mm., breadth 3.6 mm.

Colour (in alcohol).—Dorsal surface dark-grey, extensively mottled with irregular unpigmented patches.

Cephalon (Figs. 1, 2, 4).—Vertex bears 6 backwardly-directed spines. Innermost pair of spines is nearest posterior border, outermost pair of spines furthest from border; innermost and intermediate pairs subequal in length, outermost pair a little shorter. Frontal line forms a backwardly-directed ridge, with its middle third raised a little higher than the rest, and its lateral angles forming rounded right angles. Marginal line meets frontal ridge. Surface of frons very shallowly impressed on each side. Lateral processes of clypeus bluntly rounded. Eyes each composed of 12-16 ocelli.

First antenna.—Third article with apex obliquely truncate, bearing 4 aesthetascs.

Second antenna.—Length of peduncle 2.37 mm., length of articles of flagellum, 1st 0.12 mm., 2nd 0.50 mm.

Left mandible.—Incisor process has 3 teeth. Lacinia mobilis ends in 2 large teeth with smaller teeth between them. Two pencils of setae on setose lobe; one pencil behind lobe. Molar portion represented by a tuft of plumose setae set on a common basal process.

Right mandible.—Incisor process and molar portion as described for left mandible. Lacinia mobilis ends in 2 blunt teeth with spines between them. One pencil of setae on setose lobe; one pencil behind lobe.

First maxilla.—Outer lobe bears 4 broad outer teeth and 6 narrower inner teeth; all teeth simple. Inner lobe (Fig. 5) bears 2 moderately long, thick blunt pencils of setae. Outer apical angle of lobe has a fringe of setae, but no spine.

Second maxilla.—Apex divided into 2 subrectangular setose lobes; setae on outer lobe smaller than those on inner lobe.

Maxilliped (Fig. 6).—Ischion distinct; 2 long spines on its ventral surface. Division of remainder of endopodite into 2 articles indicated only by a faint, oblique suture line across its ventral surface. On inner border of first of these articles are 2 groups of setae, basal group consisting of one long and one shorter seta, distal group of one long seta and 3 shorter setae. There are 2 simple setae on outer border of endopodite; near lower one is a pencil-like process which lacks setae. Endopodite ends in a tuft of setae. Apex of endite truncate with inner angle slightly produced anteriorly and outer angle rounded; outer border of endite smoothly curved. On ventral surface near apex are 3 spines, which decrease in length from innermost to outermost. Ventral surface, anterior to innermost spine, shallowly indented.

Pereion (Figs. 1, 2, 3).—Epimera of all segments directed backwards. First epimeron with anterior angle sharply rounded, outer side of epimeron revolute, outer border thin and simple, not grooved, posterior angle bluntly rounded and not cleft. Second-4th epimera each narrowing towards outer side and ending in a recurved spine. Fifth-7th epimera each with antero-lateral border bluntly rounded, and posterior angle produced into a recurved spine. On ventral surface of 1st epimeron (see Fig. 7), far removed from outer border, is a small, bluntly rounded lobe. Surface anterior to lobe raised into a blunt ridge. On ventral surface of 2nd epimeron (see Fig. 7), in line with lobe on 1st epimeron, is a small, bluntly rounded lobe not connected with epimeral border. Dorsal surface of each segment bears 6 backwardly-directed spines. In each segment innermost pair of spines is nearest posterior border, intermediate pair of spines furthest from border. Spines on any one segment are subequal; length of spines on different segments increases slightly from 1st-7th segment. (In Figs. 2 and 3 lengths of spines appear out of proportion due to the different angles of spines in relation to the viewer.) Tergites bear scattered setae and a covering of scales—rounded scales on general dorsal surface, triangular scales on spines (including spines on epimera), with an area of gradation between these two shapes at base of each spine. Pronotum occupies about ¼ length of entire tergite; lengths in 2nd segment, pronotum 0.17 mm., entire tergite 0.75 mm.

Pereiopods.—Spines on under surface of legs too sparse to appear as a brush.

Male organ.—Lanceolate in outline, with a dorsal flap, bilobed at its apex, projecting beyond pointed apex of main part of organ. The 2 ducts open separately on dorsal flap.

Pleon (Figs. 1, 3).—First and 2nd segments both visible except at sides. Pleura of 3rd-5th segments strongly directed backwards; each pleuron with antero-lateral border bluntly rounded and posterior angle produced into a recurved spine. No lobes on ventral surface of 3rd-5th pleura. Dorsal surface of each of 3rd-5th segments bears 2 backwardly-directed spines, situated near posterior border. All spines subequal in length. Terminal segment (Fig. 8):—Lateral borders of segment incurved at about middle of its length; maximum breadth of anterior part 0.88 mm., breadth across region of greatest incurvature 0.50 mm. No increase in breadth of segment posterior to central incurvature. In posterior part, lateral and posterior borders continuous and evenly curved to base of a short, recurved, terminal spine. Length of segment to base of spine 0.68 mm., length of spine 0.10 mm. Dorsal surface of anterior part of segment strongly convex. Tergites bear setae and scales like those on pereion (with triangular scales on spine of terminal segment as well as on other spines).

First pleopod (Fig. 9).—Exopodite subtriangular with anterior and posterior borders both indented and inner posterior angle bluntly rounded. Tracheal part forms outer half of exopodite. Spines present on ventral surface near inner and posterior borders of laminar part. Endopodite styliform; its distal half curved outwards with a narrow chitinous thickening down outer edge. Dorsal surface of distal half indented by an oblique groove; outer border of groove edged with scales. A row of spinules on dorsal surface to inner side of groove.

Second pleopod.—Exopodite subtriangular with outer border indented, indentation marking division between outer tracheal part and inner laminar part; the latter greatly produced posteriorly into a long

narrow lobe, sharply rounded at apex. On ventral surface, spines occur near outer border of lobe, and an area covered by fine setae extends forwards from apex. Endopodite has 1st article quadrangular in outline; 2nd article styliform, with a chitinous thickening down inner edge of its basal 2/3 while distal 1/3 is very narrow and flagelliform. Length of articles, 1st 0.22 mm., 2nd 1.17 mm.; length of flagelliform part of 2nd article 0.43 mm.

Third pleopod.—Exopodite subtriangular, with outer border deeply incurved thus dividing exopodite into 2 lobes. Tracheal part forms outer lobe; inner lobe greatly produced posteriorly with apex sharply rounded. Laminar part has spines on ventral surface near outer border and comb-setae on inner border. On dorsal surface, near inner anterior angle, is a short ridge edged with scales.

Fourth and fifth pleopods.—Exopodites with pseudotracheae.

Uropod (Figs. 8, 10).—Basal surface of protopodite oblique, visible in dorsal view of uropod; it occupies approximately ¼ length of entire protopodite. Length of basal surface 0.22 mm., breadth of basal surface 0.46 mm., length of entire protopodite 0.85 mm. Free lobe of protopodite has inner border curved inwards, outer border shallowly curved outwards; posteriorly lobe tapers into a recurved spine which projects beyond terminal segment when uropod is attached. Exopodite inserted on dorsal surface of protopodite, away from its inner border; it is conical and elongated, but does not reach to end of spine. Area of protopodite around base of exopodite raised above rest of dorsal surface; sharp inner angle of this prominence overlaps inner border of protopodite. Endopodite inserted on ventral surface, near inner border, at base of protopodite; it is subcylindrical with apex bluntly rounded, terminating far in front of terminal segment. Length of rami; exopodite 0.27 mm., endopodite 0.17 mm.

FEMALE.

Size.—Length of largest specimen 8.7 mm., breadth 4.4 mm.

Female differs from male in the following structures:—

First pleopod (Fig. 11).—Exopodite an elongated oval in shape, with an incurvature in both anterior and posterior borders. Laminar part almost as large as tracheal part. Spines present on inner part of posterior border. Endopodite not developed.

Second pleopod.—Exopodite subrectangular, with inner part of posterior border deeply incurved and inner posterior angle sharply rounded, scarcely produced backwards. Laminar part a little larger than tracheal part. Spines present on ventral surface near inner posterior angle and on incurved part of posterior border. A conical process projecting back from inner side of protopodite probably represents endopodite.

Third pleopod.—Exopodite subrectangular, with posterior border shallowly incurved and inner posterior angle sharply rounded, scarcely produced backwards. No scaly ridge on dorsal surface.

HABITAT.

Type locality.—Description is based on specimens collected by Mr. J. A. Thomson from a limestone cave near Whitemark, Flinders Is. (Furneaux Group, Bass Strait), in March, 1960; 10 males and 13 females obtained.

VARIATIONS.

In some specimens outer border of one or both of 1st segments of pereion, instead of being evenly curved, exhibits a very small outward projection, situated a little in front of posterior angle of epimeron. Outline of projecting part varies from a blunt curve to a sharp angle (see Fig. 12).

In one specimen one of the outermost spines on the 7th segment of the pereion is bifurcated. This appears to be due to abnormal growth following a partial fracture of the spine.

ACKNOWLEDGMENTS.

I wish to thank Mr. J. A. Thomson, Department of Zoology, University of Melbourne, for his specimens of *Echinodillo cavaticus*.

REFERENCE.

JACKSON, H. G. (1933).—Marquesan terrestrial Isopoda. *Bull. Bishop Mus.*, Honolulu 114: 145-162. (Issued separately in 1933.)

THE BIOLOGY OF OOCHORISTICA VACUOLATA HICKMAN (CESTODA)

By

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(With 20 figures in the Text)

ABSTRACT

Of 234 specimens of the skink lizard, *Egernia whitei* Lacépède) examined, 112 (47.9%) were found infected with *Oochoristica vacuolata* Hickman. The lizard showed no age resistance towards infection with the cestode. The degree of infection ranged from 1 to 27 worms per host, and 45% of the infected lizards harboured more than 3 tapeworms. Infected lizards showed no resistance to superinfection. The number of gravid worms in any one lizard varied from 1 to 24 but was generally less than 11. Forty-two per cent of infected lizards harboured more than 3 gravid worms. Whilst infection of the primary host may occur in almost any month of the year, the majority of infections take place in the months of January to April inclusive. The rate of development of the strobila ranged from one proglottis every 19 days to 1 a day. Tapeworms from infections acquired in mid-summer (January to February) are gravid by May, but those from infections acquired in late summer and autumn (i.e., after February) are not gravid until the following January or February. Infected lizards kept in the laboratory voided proglottides for a period of about 16 weeks in a year, usually from December to March inclusive. Those infected with only one tapeworm passed 2 to 3 segments per week. Increases in the degree of infection were not accompanied by corresponding increases in the number of proglottides voided. The adult cestode is estimated to live for four years and shed at least 123 proglottides. It undergoes a seasonal destrobilization when its host hibernates. In the field gravid proglottides are passed by infected lizards during the months October to May. The freshly voided gravid proglottis is quite active and may move 1 to 3 cm. away from the faeces. The oncosphere is surrounded by three membranes and a colloidal material. The latter is situated between the outer and middle membranes. The oncosphere is provided with penetration glands. After ingestion by the intermediate host it escapes from its investment by means of its hooks, probably aided by the secretions from the glands. The tenebrionid, *Cestrinus punctatissimus* Pascoe serves as a natural intermediate host. In addition, experiments reveal that the cockroach *Platyzosteria melanaria* Erichson, the dermestid *Anthrenocerus australis* Hope and the carabs *Gnathaphanus adelaidae* Castelnau, *Hypharpax moestus* Dejean, *Mecyclothorax ambiguus* Erichson, *Promecoderus gibbosus* Gray and *Homothes guttifer* Germar, are capable of serving as intermediate hosts. Following ingestion, the oncosphere takes 21 to 48 hours to enter the haemocoel of the intermediate host. The rate of development of the cysticercoid is affected by the ambient temperatures. In the summer months, January and February, only 21 days are required for the larva to become fully developed.

INTRODUCTION

Early in the course of my study of the cestode fauna of Tasmania, a high proportion (66.6%) of lizards belonging to the species *Egernia whitei* (Lacépède) was found to be infected with the cestode *Oochoristica vacuolata* Hickman. This prompted a study of the life cycle of the tapeworm. Moreover, as only experimental intermediate hosts were known for the three species of *Oochoristica* whose life cycles had, at that time, been investigated, it seemed desirable that an effort should be made to discover not only the experimental but also the natural intermediate hosts of *O. vacuolata*.

Recently Gallati (1959) has described the life cycle of a further species of *Oochoristica* but stated that he made no attempt to discover the natural intermediate host of the cestode.

There have been few reported investigations of the life cycle of reptilian cestodes, in fact, the only detailed studies appear to be those of Thomas (1934, 1941) on the ophidian tapeworm *Ophiotaenia perspicua* La Rue. However, its life history requires three instead of two hosts and is therefore not comparable with that of species of *Oochoristica*.

MATERIALS AND METHODS

The investigation of the life history of *Oochoristica vacuolata* involved—

(1) a study of the food, feeding habits, reproduction, infection and local distribution of the primary host, the skink lizard *Egernia whitei* (Lacépède);
(2) the maintenance of infected lizards to provide a supply of gravid proglottides;
(3) the raising of lizards from birth under controlled conditions to provide uninfected specimens for use in infection experiments;
(4) regular collection from the field of species of animals on which the lizard was found to feed, the subsequent examination of some of them for larval stages of the cestode, and the use of others in infection experiments in order to ascertain which of the species were potential intermediate hosts;

(5) an examination of the animals found feeding on the faeces of the lizard and the probability of such animals becoming infected.

During the period 1951-1958, specimens of *E. whitei* were collected from the Queen's Domain, Hobart, in every month of the year. Each was chloroformed and measured. The body cavity was opened and the sex of the lizard determined. The gut was then removed, placed in a little water in a Petri dish and examined under a dissecting microscope. The presence or absence of food in each of the three regions of the alimentary canal—stomach, small intestine and large intestine—was noted. The food was identified as completely as possible. A record was made of the number, position and maturity of any specimens of the cestode, *O. vacuolata*, present. The occurrence in the large intestine of any free proglottides was also noted.

Specimens of *E. whitei* collected from other localities were examined in a like manner.

Infected examples of *E. whitei* were obtained from among adult lizards collected in the field and kept in the laboratory for a week to a fortnight. Each lizard observed to pass gravid proglottides was placed in a numbered wooden box 52 x 22 x 18 cm. The top of the box was fitted with a movable glass lid leaving a gap of about 10 x 22 cm. at one end. This gap was closed by a wire mesh door for ventilation. The box was filled with sterilized earth to a depth of five to eight centimetres. A small jar sunk in the soil at one end of the box was kept filled with water. A 25 watt globe placed at the end opposite the wire door provided artificial heating (25°—35° C.), when required. A flat stone, about 15 x 18 x 5 cm. placed in the box near the door served for the lizard to hide under and also for it to rub against when moulting. Gravid proglottides were removed as soon as they were found and those not required for immediate use were stored in small glass specimen tubes plugged with cotton wool and containing a label on which was recorded the number of the lizard, the date and the approximate time of the day the proglottides were passed.

Some of the infected lizards were fed only on insects and spiders collected from areas not inhabited by *E. whitei*. From these lizards information on the rate of production of gravid proglottides by *O. vacuolata* and the longevity of the mature cestode was obtained.

Having ascertained the months in which the female *E. whitei* gives birth to her young, it was possible to obtain uninfected lizards for experimentation, by collecting from the field females in advanced stages of pregnancy and keeping them in a suitable vivarium until the young were born (Hickman, 1960). As soon as possible after their birth the young lizards were removed from the vivarium and each placed in a small wooden box (18 x 10 x 10 cm.) fitted with a glass front and a wire mesh top. The box was filled to a depth of about half an inch with earth which had been previously sterilized. A small flat stone under which the lizard might retreat was placed in the box. The boxes were kept in a room which received direct sunlight for most of the morning. On hot days after a period of exposure to sunlight, the boxes were shaded to avoid overheating the lizards. After the first day, the young lizards were fed with termites, ants, beetle larvae and spiders collected from areas not inhabited by *E. whitei*. Water for the lizards to drink was periodically sprayed into the box. During the first fortnight the faeces of the lizards were collected and examined for the presence of the remains of animals other than those with which the lizard had been fed. This afforded information on whether the lizard had fed prior to its removal from the vivarium in which it had been born and hence also a check on the possibility of it having become infected before being transferred to the boxes. Other uninfected specimens were obtained by collecting newly-born lizards from the field and keeping them under observation in the laboratory for a week or more. During this time they were fed with a known food, such as termites, their faeces being examined for the remains of other foods, the presence of which would indicate that the lizard had fed in the field and hence possibly become infected prior to capture.

After determining what animals served as food for *E. whitei*, specimens of many of these were collected regularly from the field in the vicinity of the retreats and runs of the lizard. Some of them were examined for natural infections, others were kept for infection experiments. The latter specimens were placed in Petri dishes or glass tubes plugged with cotton wool and kept at room temperature for a week or more before exposure to infection. In the early stages of the investigation the specimens were examined within a fortnight following exposure, so that cysticercoids resulting from the experimental infection could be distinguished by their immaturity from those which might have been present as a result of a prior natural infection. When, in this way, a positive indication of the successful experimental infection of a particular species had been obtained, several specimens of the same species were exposed to infection and examined at intervals of more than a fortnight. By so doing it was possible to obtain further information on the development of the cysticercoid.

In view of the possibility that the adults of some species of ants might only become infected through the feeding of their larvae, an attempt was made to establish colonies of several different species of ants in the laboratory. Thus colonies of *Rhyditoponera tasmaniensis* Em. and *Pheidole spp.* were successfully established under stones in flower pots filled with earth. Each flower pot stood in a dish and was surrounded by water to prevent the ants escaping. The ants were fed with previously killed termites. Periodically gravid proglottides instead of termites were offered to the ants. Subsequently larvae, pupae and adult ants were collected from the nests and examined for cysticercoids.

By observing the insects and other animals visiting the faeces deposited by *E. whitei* near its retreats in the field and also by making use of insect traps baited with the faeces of the lizard, it was possible to gain some indication of the species which fed on the faeces and which were therefore liable to become infected.

Oncospheres from the contents of gravid proglottides smeared on a slide were examined under a coverslip supported by petroleum jelly. Release of the oncosphere from its investments was effected

by exerting a slight pressure on the coverslip immediately above the oncosphere. Vital staining of the oncosphere was obtained using an aqueous solution (1 : 10,000) of neutral red.

Insects and other invertebrates being examined for developmental stages of the cestode were partly opened in a drop of water in a Petri dish on the stage of a dissecting microscope. Specimens found to be infected were dealt with in one or other of the following ways:

(*a*) Immediately offered to an uninfected lizard.

(*b*) Dissected further and some of the cysticercoids removed, examined in a drop of water on a slide, measured and drawn under the microscope. Other cysticercoids removed, fixed in Bouin's fluid, stained in alum carmine or Ehrlich's haematoxylin and mounted.

To facilitate their examination insects were usually killed by partly crushing their heads. When handling large numbers of ants it was found helpful to give them a preliminary chilling in a refrigerator.

The alimentary canals of a number of experimentally infected beetles were fixed in Bouin's fluid, embedded in wax and sectioned at 10 micra. The sections were stained in Ehrlich's haematoxylin.

DESTROBILIZATION AND THE GRAVID PROGLOTTIS

From Table 7 it may be seen that in July and August all the tapeworms present in infected lizards from the Domain were non-gravid, but in each of the other months of the year at least some of the cestodes were gravid. In some of the lizards collected in each month from October to May, inclusive, gravid proglottides occurred free in the rectum. Thus July, August and possibly September appear to be the only months in which gravid proglottides are not passed by infected lizards.

Infected lizards collected in the field and kept alive in the laboratory in boxes not artificially heated, passed gravid proglottides usually from December to March inclusive, i.e., for a period of sixteen weeks. When kept in boxes, which during the day were artificially heated to 30± 5° C., the lizards passed gravid proglottides from September to February, a period of twenty weeks.

The tapeworms in the infected lizards kept in the laboratory, terminated the production of gravid proglottides by undergoing destrobilization. As a result chains of semi-gravid and mature segments were passed together with the remaining gravid segments. The presence of chains of mature proglottides in the rectum of several lizards collected from the Domain during May indicated that destrobilization occurs naturally. Starvation of the host for a week was found to cause destrobilization of the tapeworm. With the approach of winter *Egernia whitei* becomes less active and eats less (Hickman, 1960). This seasonal starvation might well be the cause of the natural destrobilization of the cestodes in the infected lizards in the field.

A plentiful supply of food and restricted activity due to confined living conditions, caused infected lizards kept in heated boxes in the laboratory to become very fat. Eventually they were found to reduce their food intake and as a result their tapeworms destrobilized.

Gravid proglottides are passed with the faeces or merely with the urinary excretion of the lizard. They are entire, free and active. However, those passed at the time of destrobilization are sometimes inactive and embedded in faecal material. During movement the anterior end of the detached proglottis is always that which is nearer the scolex when the segment is part of the strobila. In locomotion dorsal and ventral surfaces are not distinguishable. The anterior end of the proglottis is first raised off the ground and by the contraction of the circular muscles in the raised part, it is extended. Eventually the extended part is lowered and the hind part is brought forwards by the coordinated action of the circular muscles of the posterior half and the longitudinal muscles of the entire proglottis.

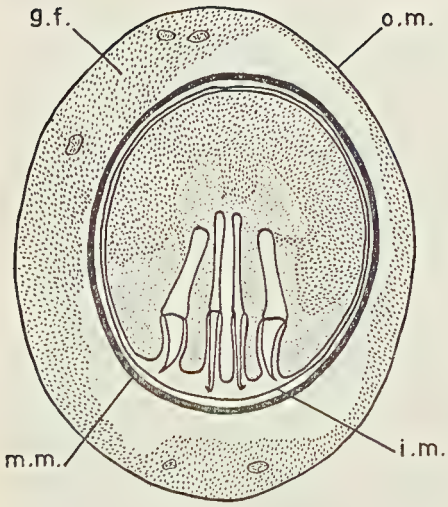
The direction of movement of the proglottis was found to be unrelated to moisture, gravity or light intensity. However, the duration of the movement was affected by moisture. Thus, provided conditions were moist the proglottis continued moving for approximately half an hour. Under dry conditions the period of movement was considerably less. As a result of its movements the proglottis usually travelled some distance from the faeces or excreta with which it had been passed. The distance travelled was found to vary with the kind of substratum on which the proglottis was voided. When passed on a rock, the maximum distance a proglottis was observed to travel was 3.0 cm. On this occasion it moved to the edge of the moist area formed by the liquid passed with the faeces of the lizard. The greatest distance moved by proglottides passed on soil was only 1.0 cm. On a glass surface they travelled distances up to 10.0 cm. On three occasions they were found to have moved up the side of a glass tank.

After cessation of movement the cuticle of the proglottis shrinks and the contents of the segment are exuded from the posterior end. The exudate is rather sticky and readily adheres to anything that touches it. The shrinking of the cuticle is apparently partly due to desiccation, for it was considerably inhibited when the proglottis was kept moist. Moreover, shrivelled proglottides were found to swell again when placed in a drop of water. After seven years in a glass specimen tube plugged with cotton wool a proglottis and in particular its exuded contents were still relatively soft. However, the exudate was no longer sticky and, as will be shown later, the oncospheres were no longer viable.

A gravid proglottis contains up to 300 eggs. As the segment shrinks the majority of the eggs are exuded with the contents.

THE ONCOSPHERE AND ITS INVESTMENTS

When exuded from the gravid proglottis the oncosphere is enclosed in three membranes (Fig. 1.). At the time of my previous description of the oncosphere (Hickman, 1954) I had not discovered the innermost investment.



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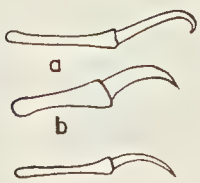

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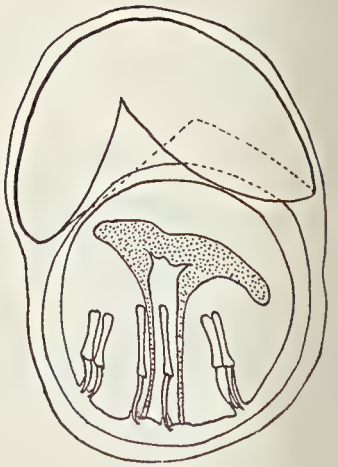

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FIG. 1.—Egg from a voided gravid proglottis, showing the membranes surrounding the oncosphere. *g.f.*, granular fluid; *i.m.*, inner membrane; m.m., middle membrane; *o.m.*, outer membrane.

FIG. 2.—Longitudinal section of egg (from transverse section of mid-gut of *Cestrinus punctatissimus*) showing the middle membrane grooved on the inside in the region near the hook.

FIG. 3.—Emergence of the oncosphere after mechanical rupture of the middle membrane. (Free-hand drawing.)

FIG. 4.—Longitudinal section of an oncosphere escaping from its investments. (From transverse section of the gut of *C. punctatissimus*).

FIG. 5.—An oncosphere nearly free from its inner membrane and exuding the contents of the penetration glands.

FIG. 6.—Hooks of the oncosphere. *a*, median hook, *b*, ventro-lateral hook, *c*, dorso-lateral hook.

Between the outer and middle membranes is a fluid, which is usually granular and contains a few scattered nuclei. When fixed the fluid coagulates and sometimes gives the appearance of an additional membrane.

The outer membrane (uterine capsule) has an irregular shape and is often slightly wrinkled. Initially it is rather thin, but in eggs kept for seven years in glass tubes plugged with cotton wool, this outer membrane had become slightly thickened.

The middle membrane (embryophore) is spherical to ovoid in shape. Externally it is marked by a reticulation of grooves. It is thicker, more rigid and more readily stained than either the external or internal membranes.

The inner membrane is very thin and is closely applied to the oncosphere. It was first detected when oncospheres which had been mechanically liberated from their embryophores failed to stain with neutral red. In order to stain the oncospheres it was necessary to rupture the inner membrane.

The oncosphere possesses three pairs of hooks (Figs. 5 & 6) and since the hook-bearing region is foremost during locomotion of the embryo, the region is considered anterior. Each hook exhibits three parts, handle, guard and blade. The handle is completely embedded in the body of the embryo; the guard is attached to the cuticular surface of oncosphere; the blade projects beyond the surface. When the oncosphere is enclosed in its membranes the blade of the hook, although appearing to be enclosed within the body of the oncosphere, is actually in a deep depression of the cuticle. Of the three pairs of hooks, one is antero-median and two are antero-lateral. The median hooks are longer and more slender than the lateral hooks. They are similar and the distal extremities of their blades are strongly curved towards what is here designated the ventral surface. The corresponding hooks of the antero-lateral pairs are similar and their blades show a gradual horizontal curvature towards the posterior. The dorsal hooks are slender while the ventral ones are stout. The average measurements of the oncosphere, its investments and hooks are given in Table 1.

The movements of the hooks of liberated and also non-liberated oncospheres were observed on a number of occasions. They comprised an initial forward movement of the median hooks accompanied by a slight forward and then backward sweep of the blades of the lateral pairs. The median pair were then drawn down and back in a clawing manner. At the same time the handles of the lateral pairs were drawn inwards and backwards so that the blades became directed forwards parallel to the blades of the median pairs.

Although a detailed histological study of the oncosphere was not undertaken, the staining of live specimens with neutral red revealed the presence of a horizontal "U"-shaped glandular structure, the two attenuated extremities of which passed forwards to apparently open between the median and lateral pair of hooks. Pores were observed with certainty only once and on this occasion a fluid was seen exuding from one of them (Fig. 5). In form this glandular structure is comparable with the glands observed by Reid (1948), Millemann (1955), Ogren (1955, 1957) and Gallati (1959) in the oncospheres of a number of different cestodes and referred to as penetration glands by Reid (1948) and epidermal glands by Ogren (1957). A variable number of large oval cells lying mainly ventral to the body of the glandular structure were also revealed by staining with neutral red. Muscular strands passing both anteriorly and posteriorly from the guard and handle of each hook were seen in both stained and unstained oncospheres. In one specimen strands from the proximal end of the handles of all hooks were seen to converge and form two groups, one passing forwards to the cuticle immediately above the median hooks, the other passing backwards to the cuticle of the posterior of the oncosphere.

During the present study only one abnormal oncosphere was observed. In this specimen there was a complete duplication of the hooks.

Viability tests were made on oncospheres from proglottides kept for various periods (up to 45 months) at room temperature in glass specimen tubes plugged with cotton wool. A total of forty-six tests were made using *Anthrenocerus australis* Hope, *Hypharpax moestus* Dejean, *Mecyclothorax ambiguus* Erichson, and *Cestrinus puntatissimus* Pascoe as hosts. The proglottides offered to the larvae of *A. australis* were left dry, whilst those offered to the other hosts were first moistened with a drop of water. Thirty-eight of the tests involved oncospheres from proglottides which had been kept for more than a month. All except two of these gave negative results. In two cases, oncospheres from a proglottis kept for 366 days proved viable on being fed to larvae of *A. australis*. In the eight remaining tests, oncospheres from proglottides stored for periods up to a month were used. All of these gave positive infections.

TABLE 1

Measurements (average, in micra) of the oncosphere, its investments and hooks. The measurements are based on 50 oncospheres taken from voided proglottides.

Oncosphere (liberated and slightly compressed) with:		
(*a*) median hooks extended	48.3	41.5
(*b*) median hooks retracted	43.7	48.3
Outer investment (uterine capsule):		
(*a*) slightly compressed	50.5	42.5
(*b*) strongly compressed	59.8	55.2
Middle investment (embryophore):		
(*a*) slightly compressed	41.5	34.5
(*b*) strongly compressed	45.0	39.0
Inner investment:		
(*a*) slightly compressed	39.0	32.0
(*b*) strongly compressed	42.6	37.0
Median hooks:		
blade	9.7	—
handle	13.8	—
Lateral hooks:		
blade	9.7	—
handle	11.5	—

TABLE 2

Analysis of the gut content of 15 specimens of *Egernia whitei* infected with very immature *Oochoristica vacuolata* having from 0 to 4 segments.

Number of segments in strobila of the cestode	Gut content														
	Formicidae	Carabidae	Chrysomelidae	Dermestidae	Scarabaeidae	Curculionidae	Diptera	Lepidoptera	Hemiptera	Orthoptera	Thysanoptera	Phalangida	Acarina	Araneida	Isopoda
0	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—
0	+	—	—	—	—	—	—	—	+	—	—	—	—	—	—
0	+	—	—	—	—	—	—	—	—	—	—	—	—	+	—
0	+	—	—	—	—	—	—	+	—	+	—	—	—	—	—
0	+	—	—	—	+	—	—	—	—	—	—	—	—	—	+
0	+	+	—	—	—	—	—	—	+	+	—	—	—	+	—
0	+	—	+	—	—	+	+	+	+	+	—	—	—	—	—
0	+	—	—	—	—	—	+	+	—	—	—	+	+	+	—
0	+	—	+	—	—	—	+	+	+	—	—	—	—	—	+
3	+	+	+	+	+	+	+	—	+	—	+	—	—	+	—
4	+	—	+	—	—	+	—	+	—	—	—	—	—	+	—
4	+	—	—	—	—	+	—	—	+	—	—	—	—	—	—

EXPERIMENTAL AND NATURAL INTERMEDIATE HOSTS

Examination of the gut contents of specimens of *Egernia whitei* collected throughout the year gave information as to what insects, &c., served as food for the lizard (Hickman, 1960). Special attention was given to the gut contents of lizards which harboured immature specimens of *Oochoristica vacullata* having a small number of segments, 4 or less. It was thought that such lizards might have acquired their infection shortly before being collected and that remains of the intermediate host might still be in the alimentary tract. An analysis of the gut contents of 15 of these lizards is shown in Table 2.

The fact that voided proglottides are usually found away from the faeces with which they have been passed, suggested that the intermediate host might be non-coprophagous. However, since gravid proglottides voided at the time of destrobilization in the cestode often remain enclosed in the faecal pellets, the likelihood of coprophagous animals serving as intermediate hosts could not be disregarded.

Animals found feeding on or showing an interest in the faeces of the lizard, included an ant (*Camponotus consobrinus* Erichson), an isopod (*Eluma caelatum* (Miers)), an oribatid mite and the larva of a dipteron. On a number of occasions *Camponotus consobrinus* was observed carrying the faecal pellets of the lizard. The isopod, mite and dipteron were found feeding on the lizards' faeces used as bait in insect traps.

Twenty-nine species of invertebrates were tested for their susceptibility to infection. They comprised representatives of the Mollusca, Myriapoda, Isopoda and Insecta (Formicidae, Carabidae, Tenebrionidae, Dermestidae, Elateridae, Curculionidae, Scarabaeidae, Orthoptera, Diptera, Lepidoptera). The results of these tests are summarised in Table 3. Unfortunately the slow rate of production of proglottides by the adult tapeworm, the relatively small number of cestodes in an infected lizard and the difficulty of maintaining a large number of lizards, limited the supply of freshly voided proglottides for experimental purposes and hence restricted the number of tests that could be made at any one time.

Dipterous larvae and oribatid mites recovered from faecal-baited insect traps were placed in faeces contaminated with gravid proglottides. Other species tested were given a preliminary period of starvation, after which they were offered either a freshly voided proglottis, or one that had been previously voided. In the latter case the proglottis was usually moistened before being offered. The interest in the segment displayed by the species being tested was noted and those species showing no interest were then offered the proglottis mixed with their food.

Isopods, carabs, tenebrionids and cockroaches showed a definite interest in and preference for freshly voided proglottides. On the other hand the larvae of *Anthrenocerus australis* generally refused freshly voided proglottides, moistened proglottides and the sticky exudate of segments. How-

TABLE 3

Summary of the infection of animals examined for experimental and natural infection.

Species	Infection			
	Experimental		Natural	
	Number of specimens		Number of specimens	
	tested	infected	examined	infected
OLIGOCHAETA	—	—	3	—
GASTROPODA—Stylomatophora	3	—	38	—
MYRIAPODA—Diplopoda	—	—	18	—
Chilopoda	3	—	3	—
ISOPODA				
Porcellio scaber	30	—	308	—
Armadillidium vulgare	5	—	79	—
Eluma caelatum	6	—	122	—
ARACHNIDA—Acarina				
Oribatidae	9	—	36	—
Unidentified	—	—	11	—
INSECTA				
Formicidae				
Camponotus consobrinus	60	—	3003	—
Camponotus sp.	—	—	54	—
Rhyditoponera tasmaniensis	40	—	1266	—
Pheidole sp.	86	—	1386	—
Pheidole sp.	168	—	653	—
Orectognathus antennatus	—	—	88	—
Polyrachis sp.	—	—	52	—
Dolichoderinae—(3 spp).	30	—	6057	—
Carabidae				
Gnathaphanus adelaidae	67	6	1135	—
Hypharpax moestus	83	40	323	—
Mecyclothorax ambiguus	33	24	158	—
Promecoderus gibbosus	5	1	15	—
Homothes guttifer	4	1	20	—
Unidentified spp. adult	—	—	245	—
larvae	—	—	26	—
Tenebrionidae				
Cestrinus punctatissimus	65	21	1356	1
Unidentified spp.	—	—	20	—
Dermestidae				
Anthrenocerus australis	1	1	12	—
Unidentified spp. adult	—	—	49	—
Byrrhidae				
Microchaetes scoparius	—	—	2	—
Chrysomelidae				
Monochirus fimbriatus	—	—	2	—
Unidentified spp. adult	—	—	115	—
Scarabaeidae				
Aphodius sp.	3	—	16	—
Unidentified spp. adult	—	—	4	—
larvae	5	—	11	—
Curculionidae				
Unidentified spp. adult	3	—	72	—
Elateridae				
Unidentified spp. adult	8	—	85	—
larvae	—	—	4	—

TABLE 3—*continued.*

Species	Infection			
	Experimental		Natural	
	Number of specimens		Number of specimens	
	tested	infected	examined	infected
Pselaphidae				
Unidentified spp. adult	—	—	77	—
Staphylinidae				
Unidentified spp. larvae	—	—	23	—
Coleoptera				
(unidentified)	—	—	42	—
Hemiptera				
Unidentified spp.	—	—	136	—
Lepidoptera				
Unidentified spp. adult	—	—	134	—
larvae	3	—	151	—
Diptera				
Unidentified spp. adult	—	—	78	—
larvae	51	—	30	—
Orthoptera				
Unidentified spp.	3	—	12	—
Dictyoptera				
Platyzosteria melanaria	4	2	35	—
TOTAL	778	96	17,562	1

ever, they would feed on the dried and shrivelled proglottis. Only one curculionid fed on a proglottis. The ants, *Camponotus consobrinus* and *Pheidole* spp. were the only other insects among those tested to show any interest in the proglottis. Only on two occasions was *C. consobrinus* observed to feed on the segments. The species of *Pheidole* were never observed feeding on the proglottides, but were often seen to take them down into their nests.

From Table 3 it may be noted that specimens of the cockroach, *Platyzosteria melanaria* Erichson, the dermestid *Anthrenocerus australis,* the tenebrionid *Cestrinus punctatissimus,* and the carabs, *Gnathaphanus adelaidae* Castelnau, *Hypharpax moestus, Mecyclothorax ambiguus, Promecoderus gibbosus* Gray and *Homothes guttifer* Germar were all found to be infected after feeding on the proglottides or on the proglottides mixed with their food. That these infections were probably brought about experimentally is apparent from a comparison of the results obtained in the case of specimens which had been subjected to artificial infection, with those for specimens of the same species which had not been so treated.

Nearly 73 per cent of the specimens of *Mecyclothorax ambiguus* and about 48 per cent of the specimens of *Hypharpax moestus* were infected experimentally. *Cestrinus punctatissimus* proved less susceptible to infection, approximately 32 per cent of the specimens being infected. Of interest is the apparent resistance to infection of the great majority of *Gnathaphanus adelaidae.* Although at least thirty-two specimens of this species each devoured an entire proglottis, only six became infected. The cysticercoids in five of these appeared exceptionally granular and opaque. The number of specimens of *Promecoderus gibbosus, Homothes guttifer* and *Platyzosteria melanaria* tested was insufficient to give an adequate estimate of the susceptibility of these species to infection. As previously stated the larvae of the dermestid, *Anthrenocerus australis* would not readily feed on freshly voided proglottides and with one exception, all individuals of this species were fed with dried shrivelled proglottides. Owing to the possible loss of viability by the oncospheres in dried proglottides, the results of the experiments with the dermestid may not indicate the true susceptibility of this species to infection. Hence only the result of the experiment in which a freshly voided proglottis was used is given in Tables 3 and 4.

Considerable intra- and inter-specific variation in the degree of infection of specimens of the various species was found (Table 4). Different individuals of the one species when fed with whole progolttides did not always become infected to the same degree. This may have been due to the variation in the number of oncospheres contained in a proglottis. However, the consistently low infection in *Cestrinus punctatissimus* would appear to be due to some factor peculiar to this species. Although some heavy infections did occur in both *Mecyclothorax ambiguus* and *Hypharpax moestus*, a comparison of the degree of infection in these species with the number of oncospheres contained in a proglottis indicates that rarely, if ever, do all the oncospheres succeed in penetrating into the haemocoel of the host.

In the search for the natural intermediate host 17,562 invertebrate animals were examined (Table 3). A naturally infected specimen was first discovered four years after the search had begun. It was identified as *Cestrinus punctatissimus* Pascoe, a tenebrionid, which as indicated above had proved susceptible to experimental infection. Four cysticercoids removed from the body cavity of the beetle were immediately pipetted down the throat of an uninfected lizard raised under controlled conditions. On dissection twenty-nine days later the lizard was found to contain one immature *Oochoristica vacuolata* having 7 segments.

At the time of the discovery of the naturally infected specimen of *C. punctatissimus*, 634 specimens of this beetle had been examined. Subsequent examination of a further 722 specimens failed to reveal any other infected individuals. The frequency of infection of the beetle is thus very low.

As may be seen from Table 2, *C. punctatissimus* was not found in the gut of those lizards, which had apparently become infected just prior to being collected from the field. Moreover, it occurred in only five of the two hundred and thirty-four lizards examined. These facts together with the low frequency of infection of the beetle can hardly account for the high frequency of infection (47.9%) of the primary host (Table 8).

From the infection experiments it is apparent that quite a wide range of insects could act as intermediate hosts. However, *C. punctatissimus* was the only species found naturally infected. If there are a number of different species acting as intermediate hosts, then, to give a 47.9% infection of the primary host none of them would necessarily need to have a high frequency of infection. This may account for the fact that no other natural infection was found among the animals examined.

Although a number of carabs appear probable alternative intermediate hosts, they showed a low frequency of occurrence in the gut of those lizards which had apparently acquired their infection immediately prior to being collected (Table 2). Moreover, not one of the 1,922 carabs collected in the field was found to be infected (Table 3).

It was found that freshly voided proglottides never remained long in the field, and hence were not likely to become sufficiently dried and shrivelled for dermestid larvae to feed on them. Therefore, it is improbable that these insects act as natural intermediate hosts.

The inadequacy of the data on the cockroach, *Platyzosteria melanaria*, makes it difficult to say to what extent this species may act as in intermediate host.

The frequency of occurrence of the Formicidae, Diptera, Hemiptera, Lepidoptera and Chrysomelidae in the food of apparently newly infected lizards (Table 2) suggests that eventually some species in one or more of these groups may be found to serve as intermediate hosts.

DEVELOPMENT IN THE INTERMEDIATE HOSTS

Ingestion of proglottides by *Cestrinus punctatissimus, Anthrenocerus australis* and *Platyzosteria melanaria* is slow and accompanied by considerable mastication. The carabs, however, eat the proglottides rapidly and do not appear to subject the segments to much chewing. If the eventual liberation of the oncospheres is dependent on the rupture of their investments (particularly the embryophore) by the action of the mandibles of the host, it would be expected that in the case of the insects that chewed the proglottis a higher percentage of oncospheres would be liberated and hence produce a greater degree of infection than in the case of insects which did not chew the proglottis. This, however, was found not to be so, since the carabs were the more heavily infected (Table 4).

The absence of a crop in *C. punctatissimus* results in the ingested proglottis quickly entering the mid-gut. Oncospheres still enclosed in their membranes were found in the mid-gut of a specimen dissected 3½ hours after it had fed on a proglottis (Table 5). The mid-gut is long, extending through the mesothorax, metathorax and anterior half of the abdomen. As a result the proglottis takes some time to pass through into the hind gut. Some non-liberated oncospheres were still in the mid-gut of specimens of *C. punctatissimus* infected 52 hours previously (Table 5). There is thus a considerable period during which oncospheres may escape from their membranes.

In the carabs, the ingested proglottis passes into an extensive crop. The period spent in the crop by the proglottis was not ascertained. However, non-liberated oncospheres were found in the mid-gut of a specimen of *Mecyclothorax ambiguus* dissected 21 hours after being fed with a proglottis. Liberated oncospheres were also present in the wall of the gut and some had succeeded in penetrating into the haemocoel. A similar location of oncospheres was found in specimens of *Hypharpax moestus* dissected 48 to 50½ hours after ingestion of proglottides.

The wall of the alimentary canal between the fore and mid-gut regions in the carabs and also in *C. punctatissimus* is furnished with spines. They are larger and more numerous in the carabs than in *C. punctatissimus*. Whether they play any part in the liberation of the oncospheres is not known. It is conceivable, however, that they could puncture the investments and thus allow fluids from the gut of the insect to enter and possibly activate the oncosphere.

TABLE 4

Degree of infection of intermediate hosts infected experimentally with *Oochoristica vacuolata*. Only the infections of those specimens which had been offered whole and freshly voided proglottides are recorded.

Number of larvae in each specimen of host	Host species and number of specimens infected							
	Cestrinus punctatissimus	*Hypharpax moestus*	*Mecyclothorax ambiguus*	*Gnathaphanus adelaidae*	*Homothes guttifer*	*Promecoderus gibbosus*	*Anthrenocerus australis*	*Platyzosteria melanaria*
1	7	7	4	4	—	—	—	—
2	4	4	1	—	1	—	—	—
3	1	3	—	—	—	—	—	—
4	1	—	—	—	—	—	1	—
5	1	2	1	1	—	—	—	2
6	1	1	1	—	—	—	—	—
8	—	—	1	—	—	—	—	—
9	—	2	—	—	—	—	—	—
10	1	2	2	—	—	—	—	—
11	1	—	—	—	—	—	—	—
12	1	2	1	—	—	—	—	—
14	1	—	1	—	—	—	—	—
16	1	2	2	1	—	—	—	—
17	—	1	—	—	—	—	—	—
18	1	1	—	—	—	—	—	—
19	—	—	1	—	—	—	—	—
20	—	—	1	—	—	—	—	—
21	—	1	—	—	—	—	—	—
22	—	1	—	—	—	—	—	—
23	—	2	—	—	—	—	—	—
25	—	—	1	—	—	—	—	—
26	—	1	—	—	—	—	—	—
34	—	2	—	—	—	—	—	—
35	—	1	—	—	—	—	—	—
39	—	—	—	—	—	1	—	—
44	—	—	1	—	—	—	—	—
47	—	1	—	—	—	—	—	—
53	—	—	1	—	—	—	—	—
60	—	—	1	—	—	—	—	—
70	—	—	1	—	—	—	—	—
83	—	—	1	—	—	—	—	—
86	—	—	1	—	—	—	—	—
97	—	—	1	—	—	—	—	—
Total infected	21	36	24	6	1	1	1	2
Total tested	65	79	33	67	4	5	1	4

In sections of non-liberated oncospheres present in the mid-gut of infected beetles, the embryophore was found grooved internally in the vicinity of the hooks of the oncosphere (Fig. 2). In transverse sections the groove was evident on opposite sides whilst in vertical longitudinal sections it was present only at one end. It appeared to extend in a horizontal plane around the inside of that half of the embryophore nearest the hooks and to coincide with the plane of movement of the lateral hooks. Sections of oncospheres in the act of escaping from their embryophores revealed that the embryophore ruptures along the groove (Fig. 4). Thus the grooving and eventual splitting of the embryophore is probably effected by the action of the lateral hooks of the oncosphere. By pushing the median hooks through the split, the oncosphere is able to pull itself out of the inner membrane and embryophore. The inner membrane,torn open as the lateral hooks scrape against the inside of the embryophore, is left behind inside the latter investment. The escape of the oncosphere from the outer membrane was not observed. However, it seems likely that the lateral hooks also tear open this membrane. There was no evidence that any one of the membranes was dissolved by the action of either the intestinal juice of the host or secretions of the oncosphere. Oncospheres, when passed out with the faeces of the host, were found to be still enclosed in their membranes.

TABLE 5

Time taken by oncospheres of *Oochoristica vacuolata* to reach the mid-gut, wall of mid-gut and haemocoel of different intermediate hosts.

Host; time and date fed with proglottis	Time and date host examined	Oncospheres	
		Period in host (hours)	Location in host
Cestrinus punctatissimus:			
1.00 p.m. 19/12/1958	4.30 p.m. 19/12/1958	3.5	Mid-gut.
9.30 a.m. 8/2/1960	9.30 a.m. 9/2/1960	24.0	Mid-gut.
3.00 p.m. 26/2/1962	3.00 p.m. 28/2/1962	48.0	Haemocoel.
4.00 p.m. 22/3/1962	8.30 p.m. 24/3/1962	52.5	Mid-gut, wall of mid-gut and haemocoel.
Hypharpax moestus:			
9.30 a.m. 7/2/1960	9.30 a.m. 9/2/1960	48.0	Mid-gut and wall of mid-gut.
11.30 a.m. 10/2/1960	2.00 p.m. 12/2/1960	50.5	Wall of mid-gut and haemocoel.
Mecyclothorax ambiguus:			
6.45 p.m. 2/3/1962	9.45 p.m 3/3/1962	27.0	Mid-gut.
4.00 p.m. 22/3/1962	1.00 p.m. 23/3/1962	21.0	Mid-gut, wall of mid-gut and haemocoel.

Oncospheres penetrating the wall of the mid-gut were seen in a number of sections, but it was impossible to determine whether they were passing through or between the cells of the enteric epithelium. They move with their hooks foremost and apparently use them to make their way through to the haemocoel of the host.

Oncospheres which had penetrated the wall of the gut were found free in the haemocoel of the metathorax and abdomen. They were lodged amongst parts of the fat body, muscles, Malpighian tubules and other organs.

In the subsequent development of the oncosphere into a cysticercoid, four stages can be recognized. *Stage* 1.—The transformation of the oncosphere into a solid ball of cells. *Stage* 2.—The formation of a cavity—the primitive lacuna—in the developing larva. *Stage* 3.—Differentiation of the scolex accompanied by an elongation of the larva. *Stage* 4.—Invagination of the differentiating scolex into the primitive lacuna, followed by the completion of the scolex and the final development of the larva into an infective cysticercoid.

Stage 1.—Soon after reaching the haemocoel the oncosphere ceases moving its hooks and becomes spherical. The internal structure of the oncosphere disappears and in its place there is formed a number of spherical cells. Multiplication of these cells follows and the developing larva soon becomes a solid ball of cells. The hooks retain approximately the same arrangement as in the oncosphere. By the end of the Stage 1 in development, the larva had increased in diameter to 80-90 micra, i.e., to approximately twice the size of the original oncosphere (Fig. 7).

Stage 2.—Future development of the larva indicates that the hook bearing region is now more appropriately regarded as the posterior.

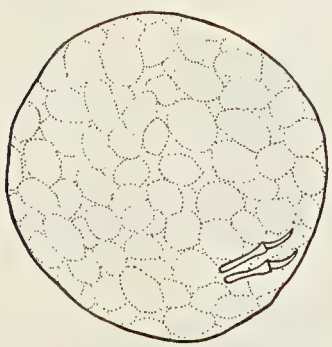
A small cavity—the primitive lacuna—soon appears among the cells of the anterior of the larva (Fig. 8a). As the larva increases in size the lacuna enlarges and becomes transversely oval. The cells anterior to the cavity multiply more rapidly than those at the posterior and cause the larva to become slightly elongated. A few calcareous granules appear among the proliferating cells. The dorso-lateral hooks loose their position and are displaced up to 69 micra from the ventro-lateral hooks towards the anterior of the larva. At the close of Stage 2 the anterior of the larva has become slightly conical and has a rather dense appearance indicating that the cells in this region are beginning to differentiate into the future scolex (Fig. 8b). The larva, now approximately 300 x 260 micra contains a lacuna 156 x 195 micra.

Stage 3.—Early in this stage the primordia of the suckers appears as dense oval clusters of cells in the anterior of the larva. The margins of the suckers soon become apparent but their musculature is not fully formed until later. Whilst the musculature of the scolex is forming, an excretory system is also developed. Two pairs of lateral canals, which in the anterior of the scolex are united by a single transverse vessel, pass to the posterior of the larva and enter separately into a small vesicle. The latter eventually opens to the exterior through a single median pore. Calcareous granules become more numerous, as many as ten being observed in one larva at this stage. During this phase of development the larva grows more in length than in width and may measure up to 492 x 315 micra (Fig. 9).

Stage 4.—The invagination of the scolex, which now occurs, marks the onset of Stage 4, the final phase in the development of the cysticercoid. As the musculature of some larvae was not fullly developed at the time of invagination, further

differentiation must take place subsequently, i.e., after the invagination of the scolex. Just how long this differentiation requires was not determined.

Fully developed and infective cysticercoids measure approximately 390 micra long and 325 micra wide and have suckers 91 to 97 micra in diameter. On being removed from the haemocoel of the host and placed in water or saline they immediately become active and evaginate their scolex. Such evaginated larvae, when fullly extended, measure up to 1.2 mm. in length and 180.0 micra in width. The scolex measures approximately 195 micra in length and 255 micra in width. Numerous calcareous granules occur, particularly in the neck region. The embryonic hooks are present but scattered in the posterior of what is destined to be the first formed segment (Fig. 10).



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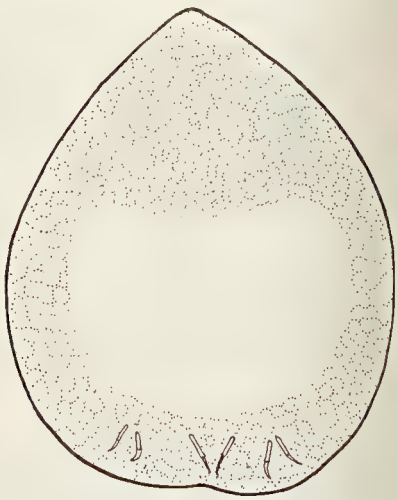

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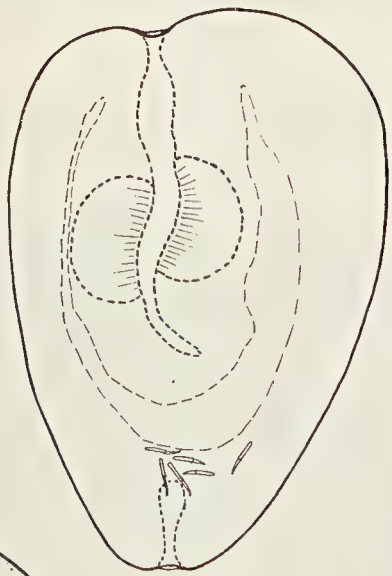

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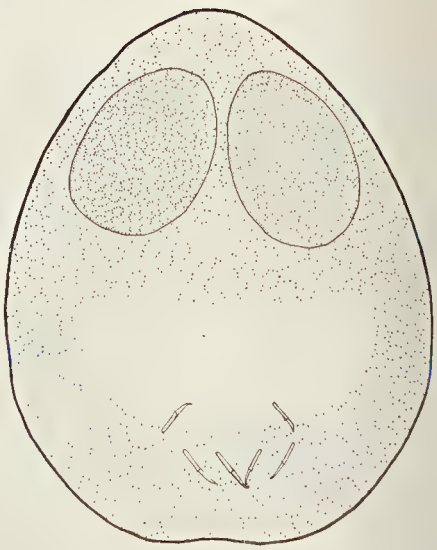

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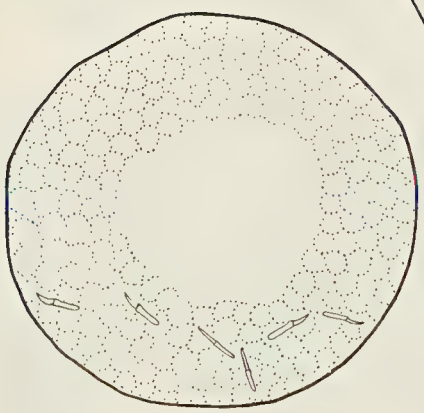

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DEVELOPMENT OF THE CYSTICERCOID

Fig. 7.—Stage 1.

Fig. 8a.—Early Stage 2.

Fig. 8b.—Late Stage 2.

Fig. 9.—Stage 3.

Fig. 10.—Mature cysticercoid.

TABLE 6

Development of cysticercoids of *Oochoristica vacuolata* in different intermediate hosts. (Grouping according to the stage reached.)

Host and date when fed with a proglottis	Date examined	Larvae		
		Period in host (days)	Number found	Stage reached (see text)
Cestrinus punctatissimus:				
Nov. 5th, 1958	Nov. 25th, 1958	20.0	4	2
Feb. 15th, 1960	Mar. 2nd, 1960	15.0	16	2
Mar. 7th, 1962	Mar, 26th, 1962	19.0	2	2
Mar. 24th, 1960	Apr. 26th, 1960	33.0	1	2
Oct. 18th, 1958	Nov. 25th, 1958	38.0	2	3
Nov. 26th, 1958	Dec. 19th, 1958	23.0	18	3
Jan. 5th, 1956	Feb. 2nd, 1956	28.0	12	4
Feb. 15th, 1960	Mar. 11th, 1960	24.0	11	4
Mar. 2nd, 1962	Apr. 2nd, 1962	30.6	1	4
Dec. 30th, 1955	Feb. 20th, 1956	52.0	14	4 (infective)
Hypharpax moestus:				
Jan. 11th, 1955	Jan. 18th, 1955	7.0	2	1
Jan. 11th, 1955	Jan. 21st, 1955	10.0	2	2
Mar. 17th, 1962	Mar. 30th, 1962	13.0	3	2
Mar. 18th, 1960	Apr. 7th, 1960	20.0	10	2
Mar. 19th, 1960	Apr. 26th, 1960	38.0	2	3
Dec. 9th, 1955	Jan. 30th, 1956	52.0	47	4
Jan. 10th, 1956	Feb. 14th, 1956	35.0	23	4
Feb. 8th, 1956	Mar. 1st, 1956	21.0	12	4
Mar. 2nd, 1962	Apr. 2nd, 1962	30.6	23	4 (infective)
Mecyclothorax ambiguus:				
Mar. 21st, 1962	Apr. 2nd, 1962	12.0	10	1
Dec. 3rd, 1954	Dec. 21st, 1954	18.0	2	2
Mar. 18th, 1962	Apr. 17th, 1962	29.8	8	2 and 3
Feb. 2nd, 1955	Feb. 27th, 1955	25.0	60	3
Jan. 24th, 1955	Feb. 25th, 1955	32.0	97	4
Jan. 11th, 1956	Feb. 15th, 1956	35.0	14	4 (infective)
Mar. 1st, 1962	Mar. 30th, 1962	29.0	19	4 (infective)
Gnathaphanus adelaidae:				
Jan. 10th, 1956	Jan. 20th, 1956	10.0	2	2
Feb. 16th, 1956	Feb. 28th, 1956	12.0	2	2
Mar. 6th, 1962	Mar. 30th, 1962	24.0	1	2
Feb. 7th, 1956	Mar. 15th, 1956	36.0	5	4
Promecoderus gibbosus:				
Feb. 21st, 1955	Apr. 2nd, 1955	40.0	2	4
Homothes guttifer:				
Jan. 31st, 1955	Feb. 28th, 1955	28.0	39	3 and 4
Anthrenocerus australis:				
Mar. 7th, 1955	Apr. 9th, 1955	33.0	4	2
Feb. 2nd, 1956	Mar. 31st, 1956	58.0	2	4
Platyzosteria melanaria:				
Feb. 25th, 1962	Mar. 18th, 1962	21.0	5	2
Mar. 4th, 1962	Apr. 2nd, 1962	29.0	5	4

TABLE 7

A summary of the infection of specimens of *Egernia whitei* examined during the years 1951-1958.

Months	Number of specimens of *Egernia whitei*					
	examined	infected	containing			
			evaginated cysticercoids	immature worms	mature worms	gravid worms
July	6	6	1	5	3	—
Aug.	6	3	1	1	1	—
Sept.	13	6	—	5	2	2
Oct.	30	18	1	9	9	10
Nov.	15	11	2	2	2	10
Dec.	8	6	—	3	3	4
Jan.	12	6	2	3	3	5
Feb.	57	23	1	10	10	21
March	40	10	2	4	3	4
April	23	14	4	11	6	8
May	18	7	—	5	3	5
June	6	2	—	1	1	1
TOTAL	234	112	14	59	46	70

TABLE 8

Length (age) of *Egernia whitei* in relation to infection with *O. vacuolata* for the years 1951-1958.

Year (Feb. to Jan.)	Lizards with						Total number of lizards examined	Total number of lizards infected	Percentage infection of total examined
	snout-vent length ≤ 55 mm.			snout-vent length > 55 mm.					
	Number examined	Number infected	Percentage infected	Number examined	Number infected	Percentage infected			
1951-2	—	—	—	45	30	66.6	45	30	66.6
1954-5	5	4	80.0	40	31	77.5	45	35	77.8
1955-6	34	5	14.7	29	20	69.0	63	25	39.7
1956-7	27	6	22.2	14	8	57.1	41	14	34.1
1957-8	34	5	14.7	6	3	50.0	40	8	20.0
TOTAL	100	20	20.0	134	92	68.7	234	112	47.9

In multiple infections the larvae were not always all of the same size nor at the same stage in development. This could be due to one or more factors. It is possible that not all the larvae entered the haemocoel at the same time. Sections of the gut of an infected *Mecyclothorax ambiguus* revealed that whilst some oncospheres were still in the crop, others had succeeded in penetrating into the haemocoel. The different positions occupied by the cestode larvae in the haemocoel of the host may favour a differential growth of the larvae. Lastly, the variations in the rates of growth may be due in part to inherited differences in the oncospheres. In heavy infections (60 to 97 cysticercoids) the ranges in size and stages reached by the larvae were the same as in light infections.

On two occasions some of the cysticercoids present in *Hypharpax moestus* were found to be enclosed in a thin membrane. As mentioned previously, *Gnathaphanus adelaidae* exhibited a marked resistance to infection. Of sixteen larvae present in one of the six infected specimens of this species, six were enclosed in thick fibrous cysts and were found adhering to parts of the reproductive organs. Some of the encysted larvae were very small and appeared to be oncospheres which had failed to develop. Others were abnormal in that although only at Stage 2, they had become markedly elongated. The larvae not enclosed in cysts were all at Stage 2 in their development but varied considerably in size.

The rate of development of cysticercoids in various intermediate hosts is evident from Table 6. The available data on the development in *Gnathaphanus adelaidae, Promecoderus gibbosus, Homothes guttifer, Anthrenocerus australis* and *Platyzosteria melanaria* is inadequate but is included for comparison. The time taken for the complete development of cysticercoids in *Cestrinus punctatissimus, Hypharpax moestus* and *Mecyclothorax ambiguus* is nearly the same. Thus specimens of these three species infected early in March were found to contain fully developed cysticercoids after 29 to 30.6 days. The cysticercoids from *H. moestus* and *M. ambiguus* proved infective. Unfortunately, in giving the specimen of *C. punctatissimus* containing cysticercoids to an uninfected lizard some difficulty was experienced and the cysticercoids may have died before being swallowed, thus accounting for the failure of the lizard to become infected. However, morphologically, the cysticercoids from *C. punctatissimus* were comparable with those from the other two hosts. Temperature has a noticeable effect on the rate of development, which is markedly slower in the colder months than in the warmer months. Owing to the scarcity of fresh proglottides it was possible to infect only a few beetles in October, November and December, but from the results obtained it is clear that the larvae in beetles infected in these months would not be fully developed in less than 55, 45, and 30 days respectively. The shortest period for the development of cysticercoids in beetles infected early in January was 28 days. Since the development of larvae to Stage 2 occurred in a minimum time (10 days) in those beetles infected early in January, it is probable that in this month development of cysticercoids is completed in less than 28 days. In February cysticercoids were found to develop in 21 days. Thus a specimen of *Hypharpax moestus* infected on February 8th and examined in March 1st was found to contain 12 fully developed cysticercoids. As mentioned previously development in March takes 29 to 30.6 days. In April it is slower and may be as long as in October and November or even longer.

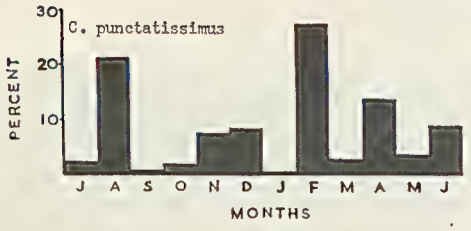
In the case of those hosts whose adults live only from Spring to Autumn, infected individuals containing fully developed cysticercoids might be expected to occur in December, January, March, April and possibly May, provided there was no infection during their larval stage. If infection of the beetles occurred in their larval stage, then individuals harbouring infective cysticercoids could occur at any time from Spring to Autumn. In species whose adults live for a longer period, individuals containing infective cysticercoids might occur in any month of the year. The only naturally infected specimen of *Cestrinus punctatissmus* so far discovered was collected in February (11/2/58) and was found to contain at least one fully developed and infective cysticercoid. Adults of *C. punctatissimus* occur throughout the year (Fig. 11) so it is possible for infected specimens to be present in any month. The cockroach, *Platyzosteria melanaria* was not collected in the field every month of the year but since it takes at least a year for the nymphs to complete development, it too must also occur throughout the year. Adults of *Gnathaphanus adelaidae* were found in every month except July and were particularly numerous in the period November to April inclusive (Fig. 12). Although adults of *Mecyclothorax ambiguus* were collected in every month except July, September and October, they were more abundant from December to March (Fig. 13). Adults of *Hypharpax moestus* were noticeably restricted to the period October to April, and most numerous in January, February and March (Fig. 14). The data on the occurrence of the other host species are inadequate.

INFECTION OF THE PRIMARY HOST

From 1951 to 1958, two hundred and thirty-four lizards were collected from the Domain and examined for the tapeworm *Oochoristica vacuolata.* No lizards were collected in 1953. A total of 112 were infected, representing 47.9% of the total number examined (Table 8).

Very immature specimens of *Oochoristica vacuolata* each with only one proglottis (evaginated cysticercoids) were found in some of the infected lizards collected from the field in July, August, October, November, January, February, March and April (Table 7). It therefore seems that infection of the primary host may occur in almost any month of the year. The occurrence of both *Cestrinus punctatissimus* and *Platyzosteria melanaria* would allow infection at practically any time of the year. The majority of recently infected lizards found were collected during the period January to April (Fig. 15). Also a particularly high percentage of infected lizards was found to harbour immature worms in April and May (Fig. 16). If the carabs, especially *Hypharpax moestus* and *Mecyclothorax ambiguus* act as intermediate hosts and only become infected when adult, their occurrence in the months of November to April might be expected to bring about, particularly in the period January to April, an increase in the number of infected lizards. However, the fact that the feeding activity of *Egernia whitei* is at a maximum from November to March may also contribute to this increase in the number infected.

There is no evidence of any age resistance, the percentage infection of large (old) lizards being higher than that of smaller (younger) lizards (Table 8). Thus, 68.7% of lizards with a snout-vent length of more than 55 mm. were infected compared with 20% of lizards with a snout-vent length of 55 mm. or less.



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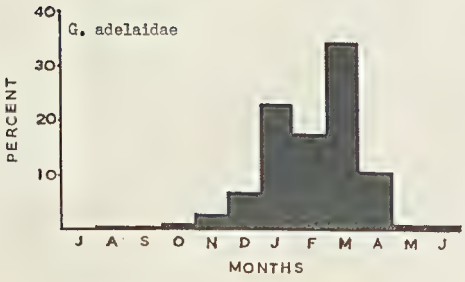

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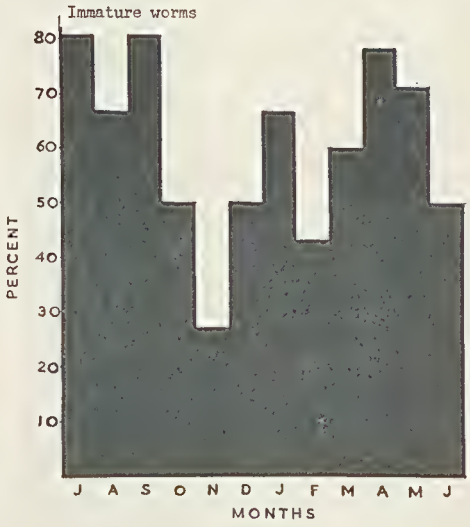

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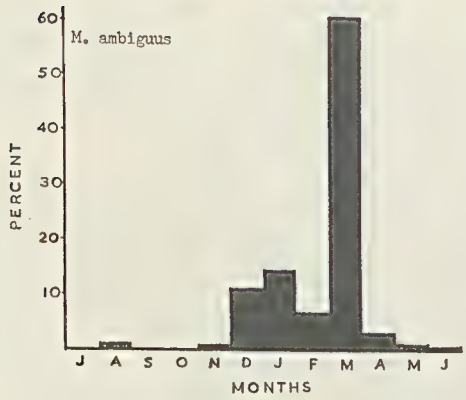

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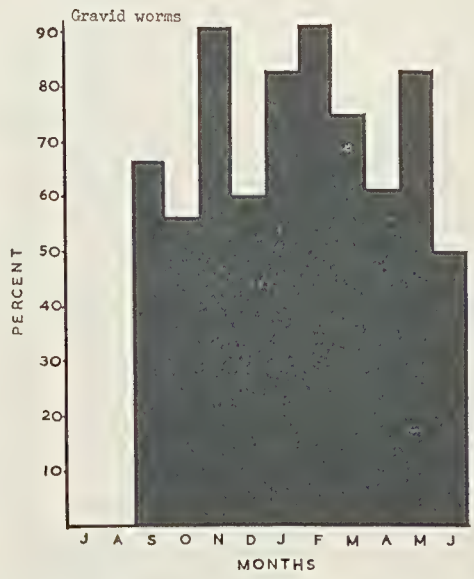

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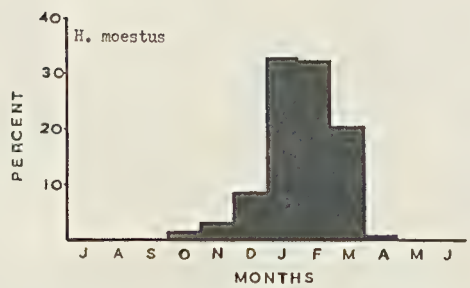

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FIG. 11.—The monthly percentages of the total number of *Cestrinus punctatissimus* collected from 1951 to 1958.

FIG. 12.—The monthly percentages of the total number of *Gnathaphanus adelaidae* collected from 1951 to 1958.

FIG. 13.—The monthly percentages of the total number of *Mecyclothorax ambiguus* collected from 1951 to 1958.

FIG. 14.—The monthly percentages of the total number of *Hypharpax moestus* collected from 1951 to 1958.

FIG. 15.—The monthly percentages of the total number of *Egernia whitei* collected during the period 1951 to 1958 and infected with *Oochoristica vacuolata* of 1 to 4 segments.

FIG. 16.—The monthly percentages of *E. whitei* collected during the period 1951 to 1958 and infected with immature *O. vacuolata*.

FIG. 17.—The monthly percentages of *E. whitei* (estimated to be more than one year old) collected during the period 1951 to 1958 and infected with gravid *O. vacuolata*.

TABLE 9

Analysis of the infection of eleven specimens of *Egernia whitei* showing multiple infections.

Number of cestodes present	Number of proglottides in strobilae cestodes
2	5, 28
2	14, 40
3	4, 14, 36
3	7, 14, 29
3	18, 34, 37
4	8, 8, 14, 40
5	3, 13, 25, 31, 33
6	1, 1, 30, 31, 34, 34
6	20, 20, 20, 38, 38, 38
6	8, 32, 33, 37, 38, 40
9	4, 4, 4, 4, 4, 4, 4, 40, 42

The degree of infection (Fig. 18) ranged from 1 to 27 worms per host for lizards from the Domain. Approximately 45% harboured more than three tapeworms. However, one lizard from East Risdon, Tasmania, was found infected with 31 tapeworms. In this case the worms were very immature (0-10 segments) and appeared to have been acquired from a single infection or at least at approximately the one time. Two other similar cases of heavy infection were found. One of these, again from Risdon, contained 20 tapeworms each with three proglottides. The other was collected on the Domain and harboured 27 tapeworms, 20 of which were immature (each consisting of only the scolex and the first formed segment). The seven other worms were fully gravid. The infection of this latter specimen indicates that multiple infections may occur. In fact, 11 other obvious cases of multiple infections were found (Table 9). Moreover, one lizard, which had been kept in the laboratory for two months and which, having voided proglottides, was known to be infected, was experimentally infected with more worms. On examination 17 days later, the lizard was found to harbour 22 tapeworms. Four of the tapeworms were gravid and had 21, 22, 23 and 24 proglottides respectively. They measured 10.5, 14.0, 17.0 and 14.0 mm in length. Each was devoid of its first formed proglottis. The other 18 worms were immature or mature having 9, 10, 11*, 12, 12, 12, 12, 13, 13, 13, 13*, 14, 14, 14, 15*, 15*, 16* and 16* proglottides respectively. In six of these worms (those with an asterisk), the strobila terminated with the first formed proglottis which still had the oncospheric hooks embedded in its cuticle. The 18 worms ranged in length from 4.5 to 8.0 mm. and were obviously from the experimental infection, whilst the four gravid worms were from some prior infection.

From the foregoing, it is apparent that infected lizards do not possess any resistance to additional infection. Since multiple infections occur, the degree of infection does not necessarily indicate the number of worms acquired from one infection. An analysis of 55 probable cases of single infections reveals that only 36.4% involved more than three worms (Fig. 19).

Nearly 42% of the lizards harboured more than three fully mature or gravid tapeworms. The maximum number of gravid worms found in any one lizard was 24 (Fig. 20). It is possible that in heavy infections (or as the degree of infection increases as a result of multiple infections) some of the tapeworms are expelled before they become gravid. Thus, six months after infection, one experimentally infected lizard was observed to void an immature worm of 10 proglottides. After 12 months the remaining worms were gravid and shed proglottides. Unfortunately, when the lizard was eventually examined it was found to have voided all the worms. Hence the degree of infection could not be determined.

RATE OF DEVELOPMENT OF THE STROBILA OF OOCHORISTICA VACUOLATA

The number of proglottides in the strobila of the tapeworms of experimentally infected lizards increased at rates ranging from one every 21.9 days to one a day (average one every three days). The tapeworms in heavy infections often differed from one another in the rate at which they developed proglottides. In one lizard infected with 13 tapeworms, the number of proglottides in the strobila of the individual worms after 41 days ranged from four to 20.

From the number of proglottides in the strobila of tapeworms from naturally infected lizards, estimated to be less than 15 months old, it would appear that the natural increase in the number of proglottides ranges from one every 19 days to one a day (Table 10). For instance, one lizard captured and examined on the 4/3/56 was found to harbour two worms of 26 and 32 proglottides respectively. The lizard measured only 43 mm. in snout-vent length and therefore had been born, at the earliest, not more than 39 days previously. Assuming the lizard acquired its infection within a week after birth, the tapeworm must have developed proglottides at the rate of approximately one a day. Thus in newly born lizards which acquire their infection early in February, the tapeworms could become gravid and shed proglottides before the end of the summer.

TABLE 10

The number of proglottides in the strobila of tapeworms taken from five naturally infected lizards estimated to be less than 15 months old.

Date lizard collected and examined	Snout-vent length (mm)	Estimated age of lizard (maximum in days)	Number of cestodes present	Range in number of proglottides in strobila of tapeworm
4/3/56	43	39	2	26-32
25/10/56	46	274	6	14-25
25/2/57	58	396	2	40-42
25/3/57	52	424	1	46
11/4/57	52	441	5	32-41

18

19

20

FIG. 18.—Frequency histogram of the degrees of infection of *Egeria whitei* with *Oochoristica vacuolata*.

FIG. 19.—Frequency histogram of the degrees of infection of 55 probable cases of single infection of *E. whitei* with *O. vacuolata*.

FIG. 20.—Frequency histogram of the degrees of infection of *E. whitei* with mature and gravid *O. vacuolata*.

The largest tapeworms from lizards estimated to be approximately one year old had 32 to 46 proglottides. A naturally infected lizard estimated to have been no more than 11 months old when collected on 28/12/54 did not void proglottides until 14/1/55. On 26/4/55 it was examined and found to harbour six gravid worms. Moreover, a lizard raised in captivity and infected experimentally on the 5/3/56 was first observed to void proglottides on the 13/1/57. It therefore seems that tapeworms acquired after February do not become gravid until the following January or February.

In November, January, February and May a high percentage of infected lizards was found to harbour gravid worms (Fig. 17). The majority of infections appear to occur in the period January to April inclusive. As indicated previously, tapeworms which had become completely gravid by the end of the summer would have recovered from their winter destrobilization by November. Thus a high percentage of infected lizards could be expected to harbour gravid worms in May, November, January and February.

A summary of the number of proglottides voided by five naturally infected lizards (A-E), kept in the laboratory, is given in Table 11. Each of the three lizards (*A, B* & *C*) infected with only one tapeworm voided two to three segments per week, lizard *D* infected with four, passed five proglottides per week and *E*, infected with five, voided six to seven per week. Thus the increase in degree of infection was not accompanied by a corresponding increase in the number of proglottides voided.

Lizard *B* was collected from the field on 28/12/54. Twenty-one days later, on 18/1/55, it was observed to void a proglottis. Its tapeworm may thus have been acquired the preceding summer and only just become gravid. The lizard voided the worm completely on 23/1/58, i.e., after approximately three years. The tapeworm had shed at least 123 gravid segments during this time. A monthly analysis of the number of proglottides voided by the lizard is given in Table 12. The majority of segments were voided during January and February. The number of proglottides passed in December reached a maximum in the third year. Thus the tapeworm recovered from the effects of the winter destrobilization quicker in the third year than in the second year. It is probable that the worm would have been larger and possessed a greater number of proglottides at the onset of the second winter than at the commencement of the first winter. After destrobilization a correspondingly greater number of mature segments would have been retained to become gravid and eventually to be voided during December. Assuming lizard *B* had acquired the infection in the summer of 1954, the tapeworm would have been approximately four years old when voided. Specimen *C* was maintained in an artificially heated vivarium and although it commenced voiding proglottides several months ahead of the other lizards and continued to do so for a longer period, the total number of segments voided in the year was about the same. Lizard *E* collected on the 28/12/54 voided a proglottis the following May. It was still infected when examined on 27/8/56. Assuming this lizard to have become infected in the summer of 1954 then the five worms were at least 2½ years old when the lizard was dissected.

TABLE 11

Summary of the number of proglottides voided by five naturally infected specimens of *Egernia whitei* kept in captivity.

Lizard	Number of cestodes	Months and number of weeks during which proglottides were voided	Number of proglottides voided	
			Total	Per week
A	1	Dec.-Feb.; 13	38	2-3
B	1	1st year: Jan.-Mar.; 10	27	2-3
		2nd year: Dec.-Mar.; 16	43	2-3
		3rd year: Dec.-Mar., 16	45	2-3
		4th year: Nov.-Jan.; 9	8	1
C	1	Sept.-Feb.; 20	44	2
D	4	Sept.-Jan.; 17	84	5
E	5	1st year: Jan.-Mar.; 13	93	7
		2nd year: Dec.-Mar.; 15	92	6

TABLE 12

Analysis of the number of proglottides voided by lizard *B* each month 1954-1958.

Year	Number of proglottides voided					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr. to Oct.
1954-5	?	?	6	13	8	0
1955-6	0	8	15	18	2	0
1956-7	0	15	10	13	7	0
1957-8	4	3	1	—	—	—
TOTAL	4	26	32	44	17	0

The lizard, mentioned previously, which had been raised in captivity and infected experimentally on 5/3/56 remained infected for four years, that is until 6/3/60. However, during this time it voided only 21 proglottides. Two proglottides were passed in the first year and none in the second year. From the 21/8/58 the lizard's vivarium was artificially heated. The lizard recommenced passing proproglottides on the 30/10/58 and continued to do so until 21/1/59. During this period 18 proglottides were passed. A further segment was voided on the 6/3/60. When the lizard was examined in the 11/2/61 no tapeworms were found in its gut. There appears no obvious explanation for the small number of proglottides passed by this experimentally infected lizard. It fed on the same variety of food as did the other five lizards. However, it was less than a month old when infected, whereas each of the other lizards was estimated to be at least two years old. Thus the total amount of food consumed by the young lizard may have been appreciably less than that taken by any one of the older lizards. This smaller amount of food consumed by the young lizard might well account for the small number of proglottides passed during the initial two years. The marked increase in the number of segments voided in the third year, when the vivarium was artificially heated, could be attributed to the greater amount of food consumed under the warmer conditions by the now older lizard.

The number of proglottides which *O. vacuolata* retains after destrobilization varies. Specimens, which had undergone destrobilization in lizards kept in the laboratory, were found to have 14 to 28 proglottides. In each instance the tapeworm had shed all its gravid segments and often some of the mature segments but never the entire strobila.

DISCUSSION

Intermediate hosts of other species of Oochoristica

Of the 69 probably valid species of the genus *Oochoristica*, 47 are parasitic in reptiles and 22 in mammals. The life cycles of only four species, namely *O. ratti* Yamaguti and Miyata (= *O. symmetrica* (Baylis) Meggitt), *O. scelopori* Voge and Fox, *O. deserti* Millemann, *O. procyonis* Chandler (syn: *Atriotaenia procyonis* Spassky) have been recorded (Rendtorff, 1948, Millemann and Read, 1953, Millemann, 1955, Gallati, 1959). However, in the case of these four cestodes only experimental intermediate hosts are known. Further only one of the four, namely *O. scelopori*, is parasitic, during its adult stage, in a reptile. The others are parasites of mammals.

Rendtorff (1948) successfully infected with *O. symmetrica* the following insects:—*Trogoderma versicolor, Attagenus piceus, Anthrenus verbasci* (DERMESTIDAE); *Tribolium confusum, T. ferrugineum* (TENEBRIONIDAE); *Tenebroides mauritanicus* (TROGOSITIDAE); *Plodia interpunctella* (LEPIDOPTERA). He was unable to infect oribatid mites belonging to the genus *Calumna,* the cockroach, *Blatta orientalis* and the tenebrionids *Tenebrio molitor* and *T. obscurus.*

Millemann and Read (1953) found that cysticercoids of *O. scelopori* would develop in *Tribolium confusum.*

Millemann (1955) obtained development of cysticercoids of *O. deserti* in the dermestid, *Dermestes maculatus;* the tenebrionids *Tribolium confusum, Gnathocerus cornutus, Tenebrio molitor* and in the lepidopteron *Ephestia cautella.* Only one of the 60 specimens of *Tenebrio molitor* tested became infected. Millemann was unable to infect *Attagenus piceus* and unidentified mites belonging to the family Acaridae (syn: Tyroglyphidae).

Gallati (1959) experimentally infected *Tribolium castaneum* with *O. procyonis.*

The results of my investigations support the conclusion that coleoptera belonging to the families Dermestidae and Tenebrionidae are potential intermediate hosts for species of *Oochoristica.* Moreover, my discovery of a natural infection of *Cestrinus punctatissimus* with *O. vacuolata,* shows that in this species at least, a tenebrionid does in fact serve as an intermediate host. In addition, for the first time, carabs and cockroaches are shown to be potential hosts. Table 13 lists the 20 insects now known as potential intermediate hosts of the five species of *Oochoristica.* In only one case, namely *Cestrinus punctatissimus,* has the insect been shown to serve as a natural host.

Up till now carabs have been recorded as intermediate hosts only for avian cestodes belonging to the genera *Hymenolepis, Raillietina* and *Choanotaenia* (Wetzell, 1938). So far only one species of *Hymenolepis,* namely *H. carioca* has been reported from carabs (Cram and Jones, 1929). However, Enigk and Sticinsky (1959) have shown that the experiment by Cram and Jones was not conclusive and that in fact carabs do not serve as intermediate hosts for this species. It should be noted that both dermestids and tenebrionids also serve as intermediate hosts for a number of species belonging to these three genera. According to Beier (1961) the only cestodes recorded from cockroaches are *Hymenolepis* sp. and *Taenia saginata.* Faust (1949) mentions three species of cockroaches which serve as intermediate hosts for *Hymenolepis diminuta.* I have been unable to find any confirmation of the record of cockroaches serving as intermediate hosts for *Taenia saginata.*

All attempts to infect mites with species of *Oochoristica* have so far failed. In contrast, mites are the only recorded intermediate hosts of species in other anoplocephalid genera. Millemann and Read (1953) considered that the biological and anatomical differences between cestodes of the subfamily Linstowiinae and other Anoplocephalid tapeworms, justified the elevation of the sub-family to the family Linstowiidae. However, Stunkard (1961) in a recent review of the taxonomy of the Anoplocephalidae concludes that "There is at present no virtue in attempts to elevate these subfamilies to family status". When the life cycles of species in other genera of the Linstowiinae are known, it may be possible to establish the true status of this group of cestodes.

The development of the cysticercoid

The pattern of the development of the cysticercoid of *O. vacuolata* agrees with the generalized scheme of development of cyclophyllidean tapeworms as proposed by Voge and Heyneman (1957). It is similar to that of the cysticercoids of *O. symmetrica, O. deserti* and *O. procyonis.* The development of the cysticercoid of *O. scelopori* has not been described.

Rendtorff found that the oncosphere of *O. symmetrica* reached the haemocoel of its host 48 hours after ingestion. According to Millemann, oncospheres of *O. deserti* take 24 hours to enter the haemocoel. Gallati found that those of *O. procyonis* reached the haemocoel after 38 hours. The oncospheres of *O. vacuolata* take 21 to 48 hours to enter the haemocoel of the host.

Rendtorff and Millemann both found that the environmental temperature of the intermediate host affected the rate of development of cysticercoids. Rendtorff discovered that, although cysticercoids of *O. symmetrica* may reach maturity in nine days during warm weather, they generally require a minimum of 18 days. Millemann obtained mature cysticercoids of *O. deserti* from adult *Tribolium confusum* after 27 days in summer. In colder months the cysticercoids were still immature after 22 days in the intermediate host. From infection experiments conducted under controlled temperature, he was able to show that at 30° C. the larvae reached maturity in 17 days, whilst at 26° C. they required 20 days. At 20° C. the larvae were still immature after 48 days. Gallati found that the cysticercoids of *O. procyonis* reached maturity and were infective after 10 days in *Tribolium castaneum* kept at room temperature (22° to 29° C.). In the present investigation, the rate of development of the cysticercoids of *O. vacuolata* was likewise found to be affected by changes in the environmental temperature of the intermediate hosts. During the warmer months (January and February) the minimum time required for cysticercoids of *O. vacuolata* to reach maturity was 21 days. In March cysticercoids required a minimum of 29 days to become infective.

The mature cysticercoids of *O. procyonis* and *O. vacuolata* are considerably larger than those of *O. symmetrica* and *O. deserti.* Those of *O. vacuolata* are slightly larger than the cysticercoids of *O. procyonis.*

The gravid proglottis and destrobilization

Freshly voided proglottides of *Oochoristica vacuolata* are quite active. There appears to be no record of the gravid segments of other species of *Oochoristica* behaving in this manner. However, the voided proglottides of *Davainea proglottina, Raillietina cesticillus, Dipylidium caninum* and *Taenia saginata* are known to exhibit considerable activity and often move some distance from the faeces with which they have been voided.

TABLE 13.

Intermediate hosts for five species of *Oochoristica*.

Intermediate host	*Oochoristica symmetrica* (syn. *O. ratti*)	*Oochoristica deserti*	*Oochoristica procyonis* (syn. *Atriotaenia procyonis*)	*Oochoristica scelopori*	*Oochoristica vacuolata*
COLEOPTERA—Dermestidae:					
Trogoderma versicolor	+	—	—	—	—
Attagenus piceus	+	0	—	—	—
Anthrenus verbasci	+	—	—	—	—
Dermestes maculatus	—	+	—	—	—
Anthrenocerus australis	—	—	—	—	+
Tenebrionidae					
Tribolium confusum	+	+	—	+	—
T. ferrugineum	+	—	—	—	—
T. castaneum	—	—	+	—	—
Gnathocerus cornutus	—	+	—	—	—
Tenebrio molitor	0	+	—	—	—
Cestrinus punctatissimus	—	—	—	—	+
Trogositidae					
Tenebroides mauritanicus	+	—	—	—	—
Carabidae					
Hypharpax moestus	—	—	—	—	+
Mecyclothorax ambiguus	—	—	—	—	+
Gnathaphanus adelaidae	—	—	—	—	+
Promecoderus gibbosus	—	—	—	—	+
Homothes guttifer	—	—	—	—	+
DICTYOPTERA—Blattidae:					
Platyzosteria melanaria	—	—	—	—	+
LEPIDOPTERA—Pyralididae:					
Plodia interpunctella	+	—	—	—	—
Ephestia cautella	—	+	—	—	—

There have been few investigations of seasonal cycles in cestodes. Up till now nothing has been recorded of the effects on reptilian cestodes of the winter hibernation of their hosts. A number of workers have found that starvation of a host may bring about the destrobilization or even the elimination of its tapeworms (Reid, 1940, 1942, Dubinina, 1949, 1950; Oliger, 1950). Reid reported that starvation of fowls infected with *Raillietina cesticillus* resulted in the destrobilization or even the elimination of the entire tapeworm. Dubinina found that, by destrobilating, *Proteocephalus osculatus* was able to survive in the empty gut of its host, *Silurus glanis*, during the winter. Oliger, from a study of the causes of destrobilization of cestodes in heath hens, concluded that it resulted from the starvation of the tapeworms and not necessarily of the host. He believed that a seasonal decrease in the quantity of starch in the food of the heath hen resulted in the sugar content of the gut of the bird becoming inadequate for the nourishment of the entire worm. Destrobilization of *O. vacuolata* occurs naturally when its host, *Egernia whitei* hibernates. It can also be brought about experimentally by the starvation of the lizard for a week. There is no evidence that the natural variation in the diet of the lizard produces destrobilization.

The longevity of few tapeworms is known and there are no data on that of species of *Oochoristica*. Lizards infected with *O. vacuolata* and kept under controlled conditions in the laboratory retained their infection for a maximum of four years. Under natural conditions, multiple infections may occur and result in a competition between the worms of the new infection and those from prior infections. The resultant degree of infection is thus a dynamic equilibrium between gain and loss of worms. Hopkins (1959) has described a similar situation in the infection of *Gasterosteus aculeatus* with *Proteocephalus filicollis*. Since, in the laboratory, no multiple infections occurred, the four years may well represent the maximum longevity for *O. vacuolata*.

The investment, structure and hatching of the oncosphere

The descriptions of the investments of the oncospheres of different species of *Oochoristica* reveal that most workers have recognized only two membranes. The outer one, sometimes called a capsule, has been considered as either parenchymatous or uterine in origin. The inner membrane (actually the middle investment), sometimes referred to as

the shell or embryophore, is usually described as being thicker than the outer membrane and separated from it by a gelatinous or granular material. Although Cohn (1902, p. 64-65) recognized three layers around the oncosphere of *O. surinamensis*, they would appear to correspond with the outer membrane, gelatinous layer and middle membrane. Zschokke (1905, p. 58) seems to have been the first to recognize three membranes.

Ogren (1957, p. 508) in describing the development of the membranes around the oncosphere of *O. symmetrica* states that " As the epidermal glands continued to develop and secrete, a membrane with metachromatic properties formed beneath the capsule and was closely applied to the oncosphere (Fig. 21)". From the figure it is clear that this membrane is the innermost of three investments. If this is so then the capsule referred to in the text is really the middle membrane and not, as implied, the outer or vitelline capsule. This interpretation is supported by the fact that in a subsequent paper, Ogren (1959 (*b*)) stated that there may be four envelopes (including the colloidal or albuminous region) enclosing the cyclophyllidean oncosphere. The fourth membrane he found to be thin and located between the inner capsule (= middle membrane) and the oncosphere. However, Silverman (1954 (*b*)) found five membranes enclosing the taeniid oncosphere and recently Voge and Berntzen (1961) observed the same number of membranes around oncospheres of *Hymenolepis diminuta*.

Ogren considered the inner capsule (= middle membrane (to be derived from colloidal secretions of the epidermal glands of the oncosphere. He compared it with the embryophore of the oncospheres of the Taeniidae and Mesocestoididae which he considered was formed from detached epidermal cells. Because of this difference in mode of formation he termed the inner capsule (= middle membrane) of the oncospheres of the Linstowiinae, a pseudoembryophore. He found that the outer capsule or shell (= outer membrane) was formed from vitelline cell products and stated that nuclei from the uterine capsule were closely attached to it in sectioned material. This statement indicates he observed, at some stage in the formation of the membranes around the oncosphere, a distinct uterine capsule. Unfortunately he made no other mention of these capsules.

In *Oochoristica vacuolata* and possibly in other species of the genus, the oncosphere (in fully gravid segments) is surrounded by three membranes and a colloidal (or albuminous) material. The latter is situated between the outer and middle membranes. The outer membrane has been termed outer shell or capsule, uterine capsule, parenchymatous capsule, vitelline capsule or shell; the middle membrane, which is usually thickened, has been termed the shell, inner shell, inner capsule, embryophore, pseudoembryophore; the inner membrane, which has generally escaped detection, is very thin and closely applied to the oncosphere.

The general structure and in particular the penetration glands (epidermal glands) of oncospheres have received considerable attention in recent years (Reid, 1948; Ogren, 1950, 1955, 1956, 1957, 1958, 1959 (*a*), and 1962; Silverman, 1954 (*b*); Silverman and Maneely, 1955; Millemann, 1955; Enigk and Sticinsky, 1957; Gallati, 1959; Sawada, 1960, 1961). Their occurrence in oncospheres of species of *Oochoristica* was first detected by Rendtorff (1958) who observed two elliptical granular areas in an oncosphere of *O. ratti* (= *O. symmetrica*). They have since been found in the oncosphere of *O. deserti* by Millemann (1955), of *O. symmetrica* by Ogren (1957) and of *O. procyconis* by *Gallati* (1959). Millemann considered them comparable with those of *Raillietina. cesticillus* as described by Reid (1958). However, he was not able to determine the anterior extent of the glands nor observe any secretory pores. Likewise, Ogren found no ducts or pores and concluded that the secretion of the glands passes through the body surface. Gallati considered they were two unicellular glands and stated that " prior to their anterior termination the cells divide into 2 lobes which appear to empty individually near the median pair of hooks ". He thus implies that there are four pores. Recently Sawada (1961) has shown that each of the glands of the oncosphere of *Raillietina cesticillus* opens by two pores (one dorsal to the other), not one, as previously recorded (Reid, 1958). Further study of the glands in *Oochoristica vacuolata* may reveal four pores instead of the two observed during the present investigation. The general structure of the oncosphere of *O. vacuolata* appears similar to that of the oncospheres of *O. procyonis* and *O. symmetrica*. Moreover, it agrees well with Ogren's (1962) theoretical diagram and his description of an infective oncosphere.

Reid (1948) suggested that the secretion of the glands might assist the oncosphere in its penetration of the gut of the intermediate host. Silverman and Maneely (1955) concluded that the secretion of the glands of the oncospheres of *Taenia saginata* and *T. pisiformis* eroded the cells of the digestive mucosa. As mentioned previously Ogren (1957) proposed as one of the functions of the secretion of these glands the formation of a membranous substance around the oncosphere. He suggested the name " epidermal glands " as a nonfunctional name to replace " penetration glands ". Sawada (1961) observing the artificial hatching of oncospheres of *Raillietina cesticillus*, found that when the oncospheres were about to penetrate the shell membrane, the glands discharged a small quantity of fluid. He also found that the glands of oncospheres which had not penetrated the digestive canal of the intermediate host showed a positive staining reaction with P.A.S. technique, whilst those of oncospheres which had penetrated showed a negative reaction. From his observations he concluded that the secretion of the glands helped the oncosphere in its escape from its membranes and also in its penetration of the gut. Although he did not indicate how the secretion helped in the liberation of the oncosphere, he suggested that the polysaccharide complexes of the glands were spent in the erosion of the cells of the gut during the oncospheres penetration into the haemocoel.

Silverman (1954 (*a*)) found that the hatching of taeniid eggs involves (*a*) the digestion of the cement which binds together the rod-shaped blocks of the embryophore and the resultant disintegration of the embryophore, (*b*) and increase in the permeability of the oncospheral membrane, (*c*) the activation of the oncosphere, (*d*) the rupture of the

oncospheral membrane by the hooks of the embryo, and (*e*) the escape of the oncosphere.

According to Gallati (1959, p. 372) "Parodi and Alcarez (1946) reported that hatching of the oncospheres of *Multiceps serialis* and *Hymenolepis diminuta* is due to the mechanical perforation of the membranes and shell by the hooks, and not the action of the mouth parts or digestive juices of the host". However, Reid *et al.* (1951) found that the shell of the egg of *H. diminuta* was cracked off by the mandibles of the host. More recently, Voge and Berntzen (1961, p, 816) have stated that "During the process of hatching (of the eggs of *H. diminuta*), mechanical friction is necessary for breaking of the egg shell and rupture of the underlying membrane. The vitelline membrane apparently is digested or dissolved by substances present in the host, while the oncosphere coat and membrane rupture only with prolonged oncosphere activity, whether or not the vitelline membrane has disappeared". They also mention the possibility of the oncosphere, during its activity, liberating substances which act upon the coat and membrane from inside.

There has been no reported investigation of the hatching of eggs of species of *Oochoristica*. Gallati (1959) did not observe the hatching of the eggs of *O. procyonis* but states (p. 372) that "Unhatched eggs were often recovered from the lumen of the gut of insects 72 hours after the beetles were fed" and concluded that "Failure of such eggs to hatch after prolonged exposure to mechanical action of the embryonic hooks and the chemical action of the host's digestive enzymes lends credence to the probability that hatching consists of emergence of the oncosphere after the egg shell has been torn by the mouth parts of the beetle".

In the case of the hatching of the eggs of *O. vacuolata* there was no indication that the investments of the oncosphere were either dissolved or disintegrated by the digestive juices of the host and there was no evidence that they were ruptured by the host's mandibles. However, the embryophore of eggs in the gut of the host was found to be grooved internally in the plane of movement of the lateral hooks of the oncosphere. It is suggested that the oncosphere, activated by certain juices of the host which penetrate the egg membranes, gouges its way out of its investments by means of its hooks. In view of the observation of Sawada (1961) it is possible that the grooving of the embryophore by the hooks is aided by secretions from the penetration glands of the oncosphere.

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PRECAMBRIAN ROCKS OF TASMANIA, PART V, PETROLOGY AND STRUCTURE OF THE FRENCHMAN'S CAP AREA

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(With 10 text-figures)

ABSTRACT

Mica and garnet schists with quartzite and associated amphibolites and eclogite form the Franklin, Joyce and Algonkian Groups. Quartzite and phyllite constitute the Mary, Scotchfire and Fincham Groups. All rocks belong to the Greenschist Facies and were affected by two periods of deformation (F_1 and F_2) during the Precambrian Frenchman Orogeny and at least one other (F_3) during the Palaeozoic. Prior to the Palaeozoic the rocks contained small to medium scale recumbent isoclinal folds; it is postulated that the metamorphic assemblages of F_1 were deformed into a large recumbent fold (Pillinger Fold) during F_2.

INTRODUCTION

Regionally metamorphosed mestasediments with minor meta-igneous rocks outcrop extensively between the King River Valley and the Central Plateau. The metamorphics are overlain unconformably by the Junee (Ordovician) Group at the Engineer Range, by the Middle Cambrian Dundas Group near Lake Margaret to the north-west, by the Junee Group to the east at the Loddon River, and by the late Precambrian (?) Jane Dolomite near Artists Hill and the Jane River.

The compilation (fig. 1) is based on unpublished work for the Tasmania Hydro-Electric Commission by S. Warren Carey, R. P. Mather, J. B. A. McKellar, I. McLeod, I. Threadgold, D. Zimmerman, D. Gee and the author.

The metamorphic rocks include various schists, phyllites, quartzites and amphibolites belonging to the Greenschist Facies of Turner and Verhoogen (1960); some details have been given by Spry, (1957) and Spry and Zimmerman (1958), and the general distribution is shown in fig. 1. Representatives of two sub-facies are recognized: the *schist-quartzite assemblage* belongs to the quartz-albite-epidote-almandine sub-facies and the *quartzite-phyllite assemblage* belongs to the albite-muscovite-chlorite sub-facies. The distribution of the rocks of the two sub-facies shown in fig. 2 does not show a simple zonal pattern.

The *schist-quartzite assemblage* consists of the belt around the north-west (Franklin Group), a similar mass just north of Mt. Mary (Joyce Group) and the schists of the Algonkian Mtn. (Algonkian Mountain Group). The *quartzite-phyllite assemblage* contains the Mary Group (through the centre of the region), the extensive phyllites in the south-east (Scotchfire Group), a narrow belt of quartzite along the western side (Fincham Group), and the quartzite at Mt. Elliot (Elliot Quartzite).

A comparison of figs. 1 and 2 shows that the sub-facies boundaries coincide with the junctions between the two major lithological assemblages and evidence given below suggests that the complex interrelations are due to large scale recumbent folding of the metamorphic zones.

The metamorphic rocks show evidence that they have undergone at least three phases of deformation and these will be referred to as F_1, F_2 and F_3. Most attention is given to the first two phases and at present F_3 will be used to include all late structures even though it is clear that they range in age from Precambrian to Devonian.

The main feature of F_1 movements was the production of a foliation S_1 which is parallel or at a low angle to S_0 (bedding). No F_1 folds have been recognized. S_1 is the weak, solitary foliation in massive quartzites, or the strong foliation in schistose quartzites; it is strongly developed in phyllites but has been largely obliterated and is only visible microscopically in the schists. The intersection of S_0 and S_1 gives a lineation L_1.

F_2 structures include the foliation S_2 which is dominant in the schists, and in many phyllites where it can be seen to be later than S_1 microscopically. It is weakly developed in quartzites but can be seen to cross the hinges of folds of S_0 and S_1; microscopically it is marked by elongate quartz and micas. Massive quartzites do not contain S_2. All of the visible isoclinal folds of all scales are attributed to this phase. S_2 is either parallel to S_1 or is so similar in direction as to be indistinguishable macroscopically except on the hinges of folds. L_2 lineations consist of fold crests, mullions, S_1-S_2 intersections, elongation of grains or grain aggregates, &c.

F_3 structures are later than the metamorphism in this area and are not associated with mineral growth. Structures include chevron folds, kinks or joint-drags, congugate folds, asymmetrical crumples, &c., with S_3 which is a fracture cleavage. The orientation of S_3 and associated L_3 is variable with respect to the older structures.

Palaeozoic

- JUNEE & ELDON GROUPS WITH BASAL OWEN CONGLOMERATE

Precambrian

YOUNGER

- pCj JANE DOLOMITE

OLDER

- pCs SCOTCHFIRE GROUP
- pCe ELLIOT QUARTZITE
- pCfi FINCHAM GROUP
- pCf FRANKLIN GROUP
- pCm MARY GROUP
- pCjc JOYCE GROUP

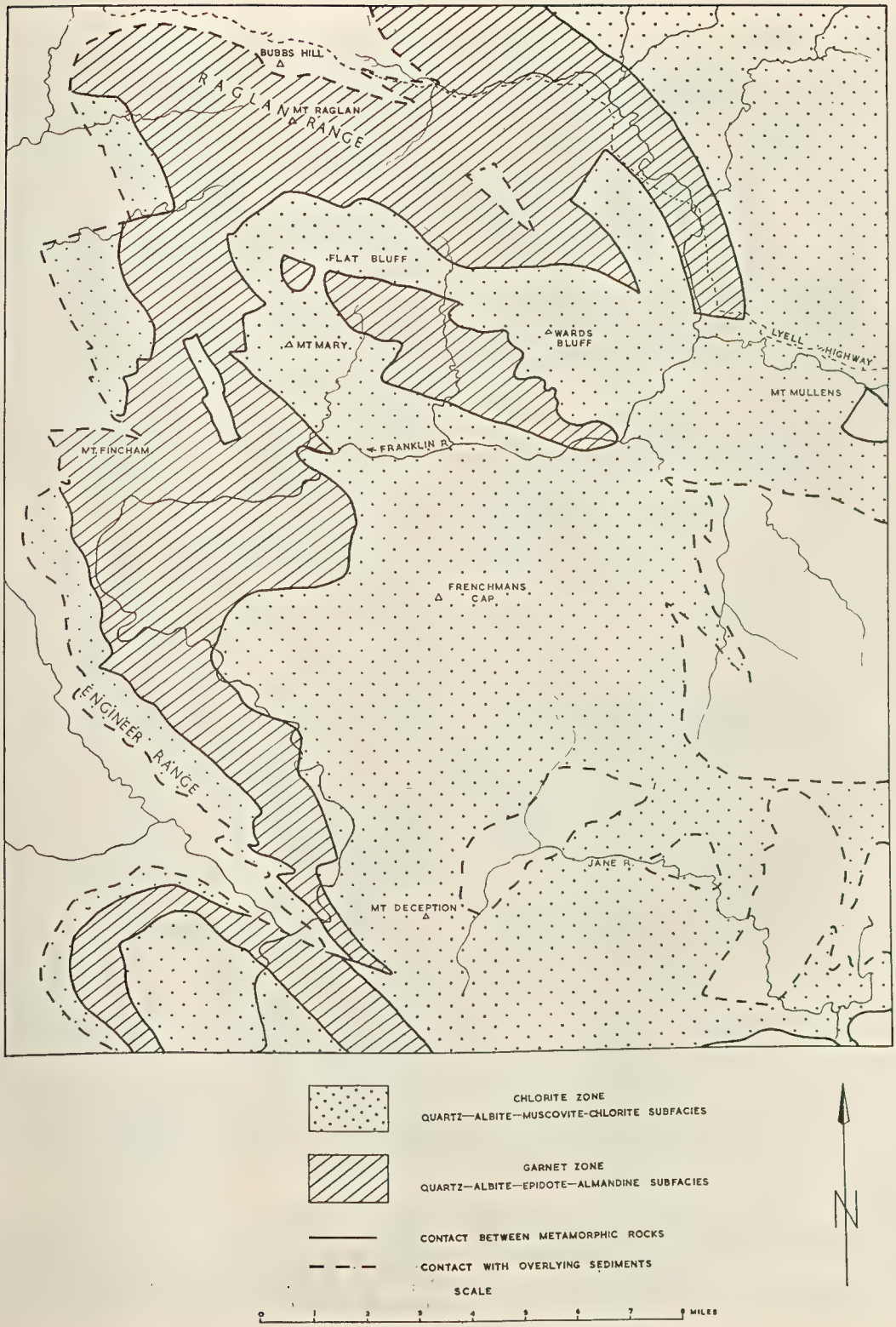
- DIP & STRIKE OF BEDDING OR MAJOR FOLIATION
- PLUNGE OF LINEATION
- ANTICLINAL AXIS
- SYNCLINAL AXIS
- FAULT
- LITHOLOGICAL BOUNDARY

SCALE

0 1 2 3 4 5 6 7 8 MILES

N

1. Geology of the Frenchmans Cap area. (with acknowledgment to the Geological Society of Australia)



2. Distribution of metamorphic facies in fig. 1.

Structural Evolution

Evidence will be adduced to show that metamorphism took place in two stages with the higher grade coinciding with F_1. The small-scale folds belong to F_2 and it is postulated that the metamorphic zones were folded into a very large recumbent fold (Pillinger Fold) during F_2. The whole region was folded again several times, most notably during the Tabberabberan Orogeny about north-south axes (Frenchman Anticlinorium) and west-north-west axes (Mary Antiform, Collingwood Synform, &c.).

QUARTZITE-PHYLLITE ASSEMBLAGE

This comprises the Mary Group, Scotchfire Group, Fincham Group, Elliot Quartzite and possibly the Mt. Maud quartzite. The Mary Group is best known.

MARY GROUP

Massive quartzites, quartz schists and phyllites occur near Mount Mary (Spry, 1957).

The sediments, particularly the phyllites, are cut by a number of foliations, of which S_1 and S_2 are prominent. In some places original bedding can be recognized where it is marked by sedimentary structures such as ripple marks and cross-bedding and the major foliation is commonly parallel or sub-parallel to the bedding. If it is assumed that the major foliation is still parallel to bedding when the bedding surface is not clearly recognizable, then the beds at Mt. Mary represent a thick succession dipping south-west and those on Wards Bluff represent the same succession dipping north-east. Both lie above the Joyce Group which occupies the core of the Mary Antiform. The lack of correspondence of stratigraphic sections a few miles apart indicates that the Antiform is not a simple structure and this is confirmed by the apparent thickening of the Mary Group around the nose of the Antiform from 500 ft. at Mary Creek to 2000 ft. at Mt. Maud. It is suspected that the rocks are tightly isoclinally folded but insufficient facings have been found to confirm this.

The three main rock types (massive quartzite, quartz schist and phyllite), consist almost entirely of quartz and sericite and the rocks differ mainly in grainsize and the relative proportions of the two minerals.

Massive Quartzites

The abundant massive white quartzites are thickly bedded and are the only rocks to contain recognizable bedding.

In thin section, massive quartzites (such as 6223*, 6225, 6251, 6296, 6311 and 7039) are seen to consist almost entirely of quartz with accessory sericite, tourmaline, zircon and iron ore. Large (.5 to 1 mm.) xenoblastic to lenticular quartz grains are set in a fine-grained ground-mass of quartz. (N.B.—No. 6225 from Mt. Mary, 6783 from Mt. Deception and 6827 from Junction Peak). The large quartz grains show pronounced undulose extinction and deformation lamellae; the small quartz crystals are fresh, clear, elongate and free from undulosity and lamellae. Some specimens consist of large quartz crystals with sutured margins and a few randomly oriented micas. As the proportion of small quartz grains increases from specimen to specimen, so does the degree of preferred orientation (by external form) of the quartz and the degree of development of a macroscopic lineation.

Petrofabric diagrams of the massive quartzites will be published elsewhere. A detailed petrofabric examination of similar rocks from Goat Island indicates that this mortar texture was developed in at least two stages. A coarse granular texture was formed at an early stage (F_1?) and was replaced wholly or partly by crushing of the large pretectonic quartz grains with syntectonic crystallization of small elongate crystals (F_2?). The later stage appears to have affected the micaceous quartzites more than the purer arenites. Chronological analysis of the relative roles of crystallization and deformation in the fabric evolution of the quartzites is rather ambiguous and largely depends on analogy with the associated metapelites.

Quartz Schists

The most common rock in the Mary Group is a white platy siliceous rock named (Spry, 1957) a micaceous quartzite or quartz schist.

Under the microscope, quartz schists (such as 6224, 6226, 6229, 6257, 6310, 6991, 6992, 7033, 7430, 7035 and 7044) consist of small, approximately equidimensional, grains of quartz averaging about .05 mm. across, with up to 5% of tiny parallel sericite flakes; accessories are tourmaline, rutile, iron ore and zircon.

A chemical analysis of No. 6220 from Mt. Mary (Table I) indicates that it contains about 97% quartz and 3% mica (mainly sericite).

Specimen No. 6970 from just west of the Franklin-Loddon River junction represents the moderately deformed quartz schists. It has a single foliation (S_1?) and a pronounced lineation. The quartz is slightly elongate and is somewhat undulose. Skeletal tourmaline is evidently posttectonic.

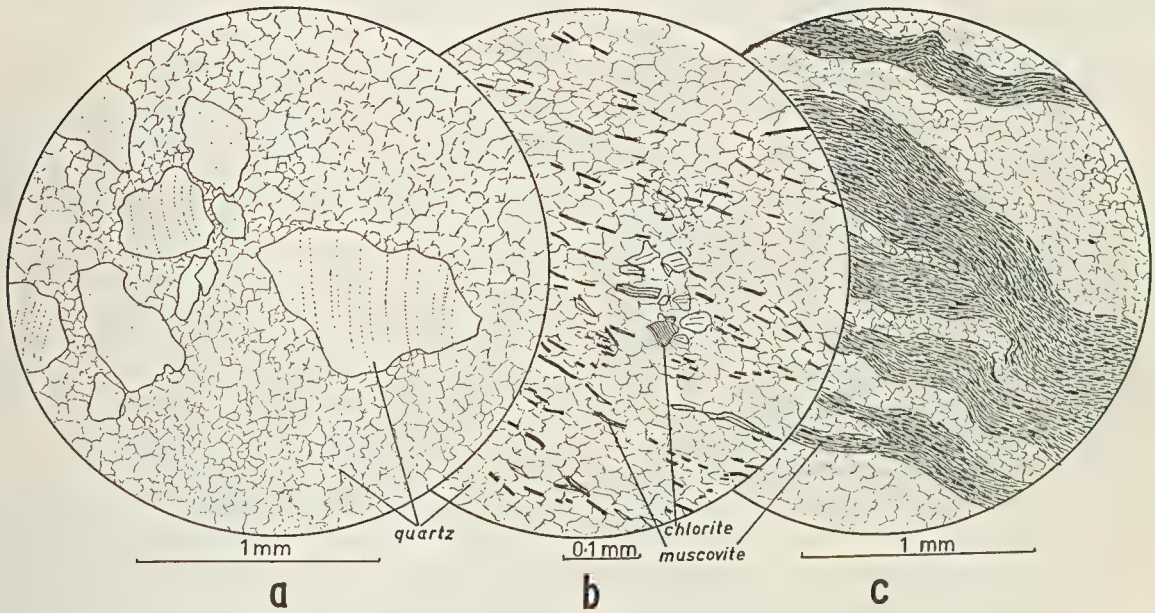
Specimen No. 6815 is apparently more deformed as the macroscopic foliation is strong, and the quartz markedly elongate.

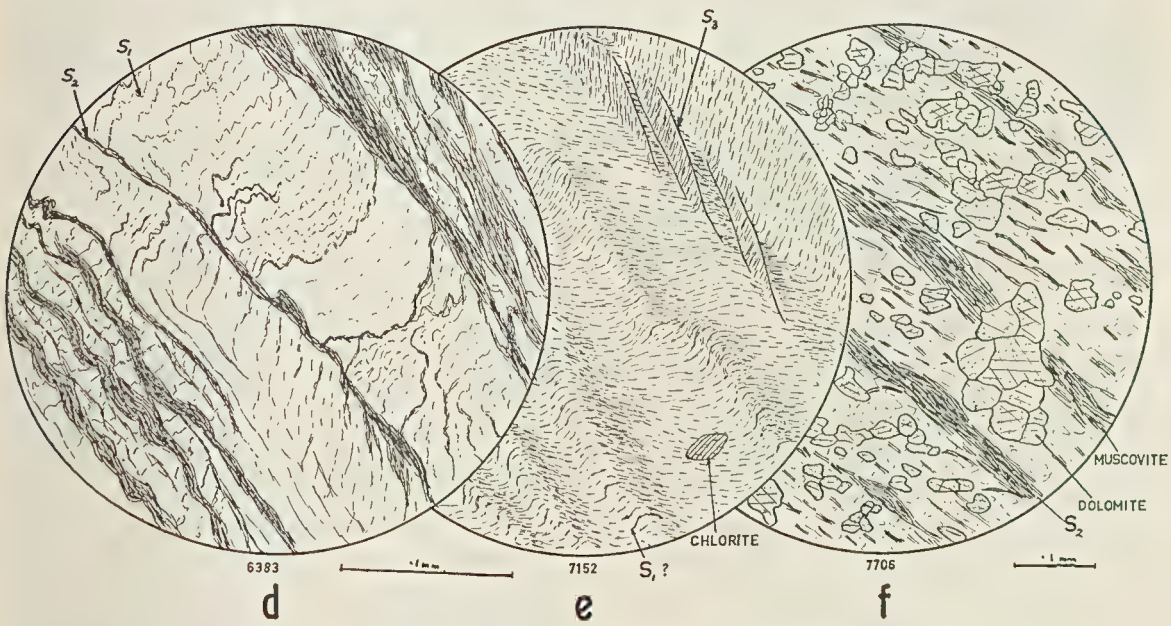
Specimens which contain more mica than the common schist described above, have a strong macroscopic foliation, a strong degree of dimensional preferred orientation of quartz, and have apparently been more strongly deformed. The exact nature of the sediments from which the quartz schists were derived is not clear; they may have been coarse quartz-sandstones which have been strongly granulated but were probably siliceous siltstones. They are intermediate between the massive quartzites and the phyllites in composition.

Phyllites

Light to dark-grey coloured, fine grained, strongly foliated rocks occur throughout the Mary Group; particularly prominent is the apparently basal formation which rests on the Joyce Group at Flat Bluff. The phyllites are composed of quartz grains averaging about .05 mm. across with abundant

* Numbers refer to specimens in the collection of the Department of Geology, University of Tasmania.





3. Textures of Mary Group rocks:
   (*a*) massive quartzite with mortar texture.
   (*b*) quartz schist.
   (*c*) phyllite; S_0 and S_1 essentially parallel.

Textures of Scotchfire Group rocks:
   (*d*) phyllite with S_1 and S_2.
   (*e*) phyllite with S_1 (?) and S_3
   (*f*) calc-schist with dolomite posttectonic to S_2

sericite and accessory chlorite, tourmaline, rutile and iron ore. Typical are 6253 from Flat Bluff, 6307, 6309, 6239, 6227, 6242 and 6243 from Mt. Mary, and 7010 from Twelvetrees Range.

The chemical analysis (No. 1 in Table I) shows the rock (No. 6227) to have the composition of a siliceous siltstone, a mature sediment from a stable tectonic environment.

Although mineralogically and chemically simple, the phyllites are structurally complex and have some of the attributes of phyllonites. They are tightly contorted into recumbent isoclinal folds a few inches across, with sheared out limbs, fold-mullions, quartz-rods and quartzite boudins. The major microscopic foliation is parallel to a fine compositional banding but it will be shown that this is S_2; it is younger than another tectonic foliation S_1; bedding (S_0) has been mostly destroyed.

Some phyllites of simple appearance consist of alternate layers of fine sericite and quartz but the complex structures of fig. 4 are more typical.

Three microscopic foliations can be recognized:

(*a*) a weak irregular one marked by tiny whisps of twisted sericite;

(*b*) a strong one marked by thin compositional banding;

(*c*) a fracture cleavage across crenulations of (*b*).

It is not possible to be certain from a microscopic examination of most specimens whether any of these S-surfaces correspond to bedding. In fact it is not clear in which order the S-surfaces of some specimens formed (e.g., fig. 4). The latest is certainly the fracture cleavage but the major foliation is only recognized as S_2 in a few specimens; it grades into a foliation more positively identified at S_2 in Franklin Group schist north-west of Flat Bluff.

The foliations can be clearly distinguished microscopically in some specimens; a coarse lithological layering is the oldest structure and is probably S_0. A foliation S_1 formed by parallel mica flakes is parallel to it. Both S_0 and S_1 have been crumpled and an oblique strain-slip cleavage has formed; packing of mica flakes along this S_2 produces a fine lithological layering.

FINCHAM GROUP

McLeod (1956) and Mather (1955) mapped a belt of quartzites and phyllites mainly along the Engineer Range and named it the Fincham Group from its occurrence at Mt. Fincham. The Group is overlain unconformably by Ordovician Owen Conglomerate at the Engineer Range and appears to rest on schists of the Franklin Group.

Measuring structural thicknesses perpendicular to apparent bedding suggests over 3000 ft. near Mt. Fincham, about 2500 ft. two miles to the south and about 300 ft. two miles further south. This variation must be at least partly due to overlap by the Ordovician sediments.

The rocks are somewhat similar to those of the Mary and Scotchfire Group and the group consists of phyllites and quartz-schists with rare massive quartzites. The quartz-schists and phyllites are commonly contorted on a small scale and contain isoclinal folds so that it is impossible to follow beds any distance along the strike or to correlate sections even a mile apart.

Phyllites

The simplest phyllites (e.g., 7036 from near the apparent base of the Group) are grey crenulated rocks. In thin section they are strongly foliated and consist of quartz, muscovite and chlorite. The major foliation (S_2) is produced by layers of mica but small flakes of mica in the quartz-rich bands are orientated obliquely and define another foliation (S_1).

Phyllites such as 7037 from the top of the Engineer Range are typical and possess textures with considerable chronological complexity. Two foliations are shown; the main one consists of layers alternately richer in quartz and in muscovite and is essentially planar apart from a few small undulations. It is younger than a strongly folded foliation (S_1) produced by small muscovite flakes and lenticular quartz crystals. A pair of foliations with these characteristics is very common in Precambrian metamorphic rocks from all parts of Tasmania and although the relative ages of the two foliations are not immediately apparent in all specimens, the greater deformation of S_1 is taken to be evidence that it is older than S_2. Each foliation is taken to indicate a stage in the deformation of the rock. It is not clear whether or not S_1 is bedding but as it is outlined by mica flakes it is probably tectonic. The small micas along S_1 are probably syntectonic to the first stage of deformation (F_1) and pretectonic to the second stage (F_2) and are twisted. The large micas along S_2 are probably syntectonic to F_2 but include some twisted muscovite from F_1 rotated into the later foliation. Chlorite occurs as syntectonic flakes along S_1 but much of it is randomly disposed and is posttectonic to F_2.

A weak and widely spaced fracture cleavage (S_3) occurs along the axial surfaces of small folds of S_2 but no mineral growth is associated with it.

Quartz Schists and Massive Quartzites

These are subordinate to the phyllites although quartz-schist is abundant. Petrographically they resemble rocks already described in the Mary Group and the descriptions will not be repeated. One specimen of massive to platy quartzite (No. 7039) from the top of the Engineer Range is intermediate in character between quartzite from the Mary and the Franklin Groups. It is medium to fine-grained and is composed largely of strongly elongate quartz crystals with a little sericite and chlorite in small parallel flakes.

ELLIOT QUARTZITE

The massive white quartzite forming Mt. Elliot extends towards the Mary Group south of Frenchmans Cap and may be continuous with it. Small ridges on the Lightning Plains were said by Wells (1957) to consist of similar quartzite (specimens 6356, 6357) and to be anticlinal crests plunging beneath the Scotchfire Group. Wells considered that the Elliot Quartzite appeared again to the east near Algonkian Mountain (specimens 6433, 6435) and at Warnes Lookout (6426).

4. Complex fabric of Mary Group phyllite with S_1, S_2 and S_3.

The Elliott Quartzite is indistinguishable both microscopically and macroscopically from the massive quartzite of the Mary Group but it cannot be assumed that the two are equivalent in the absence of detailed mapping.

Specimen No. 6335 from Mt. Elliot is a massive white quartzite with sand-size quartz grains in a white siliceous matrix. Mortar structure is visible in thin section where a few large undulose quartz grains (.5 to 1 mm. in diameter) are set in a matrix of quartz averaging .05 mm. diameter. About 2% of fine muscovite shows a weak preferred orientation.

SCOTCHFIRE GROUP

This term was first used by Wells (1957) to refer to the phyllites, schists, quartzites, and dolomites along the Scotchfire Creek and the surrounding area. Spry and Zimmerman (1959) included phyllites, dolomites and quartzites along the Lyell Highway (38 miles from Queenstown) in the Scotchfire Group.

Schists

Fine grained schists and phyllites are the most common rocks in this group. They range in colour from grey to green and are generally strongly foliated and crenulated. The three major minerals present are quartz, sericite (or muscovite) and chlorite; albite is rare and accessories are tourmaline, iron ore, zircon and rutile. Carbonate occurs in some varieties.

The simplest variety, both mineralogically and structurally (e.g., 6259), contains one foliation. Such rocks are fine grained and schistose, consisting chiefly of quartz and muscovite. The mica occurs in thin sub-parallel layers outlining the foliation and in quartz-rich bands between the micaceous layers.

Quartz is present as ragged crystals about .2 mm. across set in a matrix of smaller crystals about .05 mm. across. The micaceous layers average about .1 mm. in thickness and are gently crenulated in open folds about 1 cm. in length but the layers themselves vary in thickness and direction; the layers are approximately parallel but intersect each other and merge together. The foliation appears to be due to the aligning of mica flakes along closely spaced shear surfaces which were later crenulated.

Most of the fine grained schists or phyllites consist of about 60% quartz, 30% muscovite and 10% chlorite, but vary in the complexity of their structure.

Specimens 6362, 6364, 6465 and 7152 are moderately deformed representatives of the Scotchfire Group. They are composed of alternate, very irregular bands which are rich in quartz or in muscovite.

The quartz-rich bands are approximately 1.5 mm. thick and contain strongly elongate crystals ranging from .05 to .25 mm. across. The layers vary considerably in thickness and some are lenticular; the tiny muscovite flakes within the layers are discordant with the direction of the boundaries of the layers in some places. The micaceous layers consist of whispy muscovite flakes approximately .02 mm. long with lenticular quartz crystals. The micas are sub-parallel but are contorted and very irregular in direction. Chlorite occurs as small lenticular clots with the cleavage generally at a large angle to the foliation of the rock.

Others (e.g., 6364) are very rich in muscovite as a mass of interwoven crenulated flakes. Many mica flakes are parallel to each other and to elongate aggregates of quartz but this foliation has been crinkled and is difficult to recognize. Original bedding cannot be recognized with any certainty but is probably represented by irregular lenticular quartz aggregates; these appear to have once been quartz rich layers oblique to the foliation but movement along the foliation has folded and disrupted the layers, torn them apart, and rotated them.

The most characteristic of the Scotchfire phyllites are the fine-grained glossy, green, strongly foliated and lineated rocks such as 6336, 6366, 6393, 6966, 6974, 6430, 7152 and 7157. Under the microscope they can be seen to consist chiefly of quartz, muscovite and chlorite but their structure is very complex; three foliations are present but there is no evidence that any represents the original bedding. The most prominent foliation (S_2) is marked by layers alternately richer in muscovite or quartz. Remnants of an older foliation (S_1) are present between the layers which themselves are tightly folded. A third foliation (S_3) is a fracture cleavage along one limb of the folds of S_2. This multiplicity of foliations is present in many of the Mary and Fincham Group phyllites and some Franklin Group schists.

It is difficult to describe adequately the structure of these rocks and reference should be made to fig. 3 which depicts some typical varieties. The relative ages of the foliations can be established from the data obtainable from specimens such as No. 6336 and it is important that the strongest foliation marked by compositional banding is not bedding but is later than at least one other foliation.

A chemical analysis of a green phyllite (No. 7310) from the Scotchfire Group is given in Table I. It outcrops on the Lyell Highway below Mt. Arrowsmith and consists of approximately 40% of quartz, 50% of fine-grained muscovite and 10% of chlorite with accessory tourmaline and iron ore. The structure is similar to that described in previous specimens. The analysis indicates that the original sediment was siliceous and clay-rich, probably a siliceous siltstone. The analysis shows many similarities with that of the Mary Group phyllite given earlier except that potash is higher. The range of composition of four Franklin Group schists is so great that the Scotchfire phyllite can be said to be similar to them. The main difference is that the Scotchfire is very low in soda (albite is uncommon in the Scotchfire rocks but is common in the Franklin Group). Lime is very low in this rock as it is in all schists and phyllites from this area except No. 6372. This is a light-grey phyllite forming a thin layer within slates from the Jane River. In thin section it is a fine-grained, irregularly textured rock consisting of about 60% quartz with muscovite, chlorite, actinolite and zoisite; accessories are albite, iron ore, tourmaline, sphene and zircon.

This rock has much lower potash than most other rocks from the area and has the highest lime of any; magnesia is also quite high. Thin bands of dolomite and dolomite-schists occur in the Scotchfire Group near here and the most likely origin for the rock is that it was originally a slightly dolomitic and siliceous siltstone. An alternative explanation is that it might have had a small tuffaceous content but there is no other evidence here of contemporaneous volcanism.

Calc-mica schists from Carbonate Creek and near the 40 mile post on the Lyell Highway near Mt. Arrowsmith, were briefly described by Spry and Zimmerman (1958); Wells (1957) mentioned similar types in the Jane River area. They are grey to brown, fine-grained, foliated and lineated schists. No. 7706 contains about 40% of dolomite and 40% quartz with the remainder muscovite and chlorite. No. 7703 contains quartz, muscovite and dolomite and has three foliations. Muscovite, quartz and chlorite grow along S_1 and S_2 and are apparently syntectonic to F_1 and F_2. Only dolomite grows along S_3. As shown in fig 3 crystallization of the carbonate is mostly posttectonic as it occurs in relatively coarse patches or even veins transgressing the foliation and shows little evidence of an elongate habit. It is possible that the carbonate was introduced metasomatically quite late in the rock's history.

No. 6417 is a dark coloured, fine-grained schistose and contorted dolomite. In thin section it contains of about 55% of dolomite as shapeless grains .05 mm. across, with 30% of quartz and 15% of muscovite. The schistosity (S_2) is caused by irregular, intersecting thin bands of fine-grained parallel flakes of muscovite. Between the foliation planes are abundant contorted flakes of mica (S_1). The texture is somewhat simpler but is nevertheless very similar to that of the calcschists described above.

No. 6392 occurs as a 12' layer within the Scotchfire schists in upper Thirkell Creek. It is a medium grained reddish coloured rock with numerout white quartz veins about $\frac{1}{8}$" wide. Under the microscope it consists mainly of unevenly textured dolomite with crystals ranging from .6 mm. to .06 mm. showing sutured margins. The larger dolomite crystals show various deformation effects such as weak undulose extinction, multiple twinning, curved twin planes, and twin lamellae cut by later glide planes which disrupt them and displace the lamellae in sections. Abundant small quartz crystals and haematite are also present.

Specimen No. 6416, also interbedded with Scotchfire schists in upper Thirkell Creek, is a fine-grained dolomite, strongly laminated with alternate pale grey and pink laminae. In thin section it is very fine-grained and contains about 60% of dolomite, 20% of quartz, 15% of white mica and 5% iron ore granules. The quartz, together with some of the mica, tends to be concentrated in bands which are strongly contorted on a small scale and which probably represent bedding. A foliation, caused by parellel mica flakes at 30° to the lamination, is prominent within the laminae but is difficult to see in the dolomite-rich zones between the layers. The analysis in Table I indicates that it is a dolomite with about 25% of quartz, 10% of muscovite and $2\frac{1}{2}$% of magnetite.

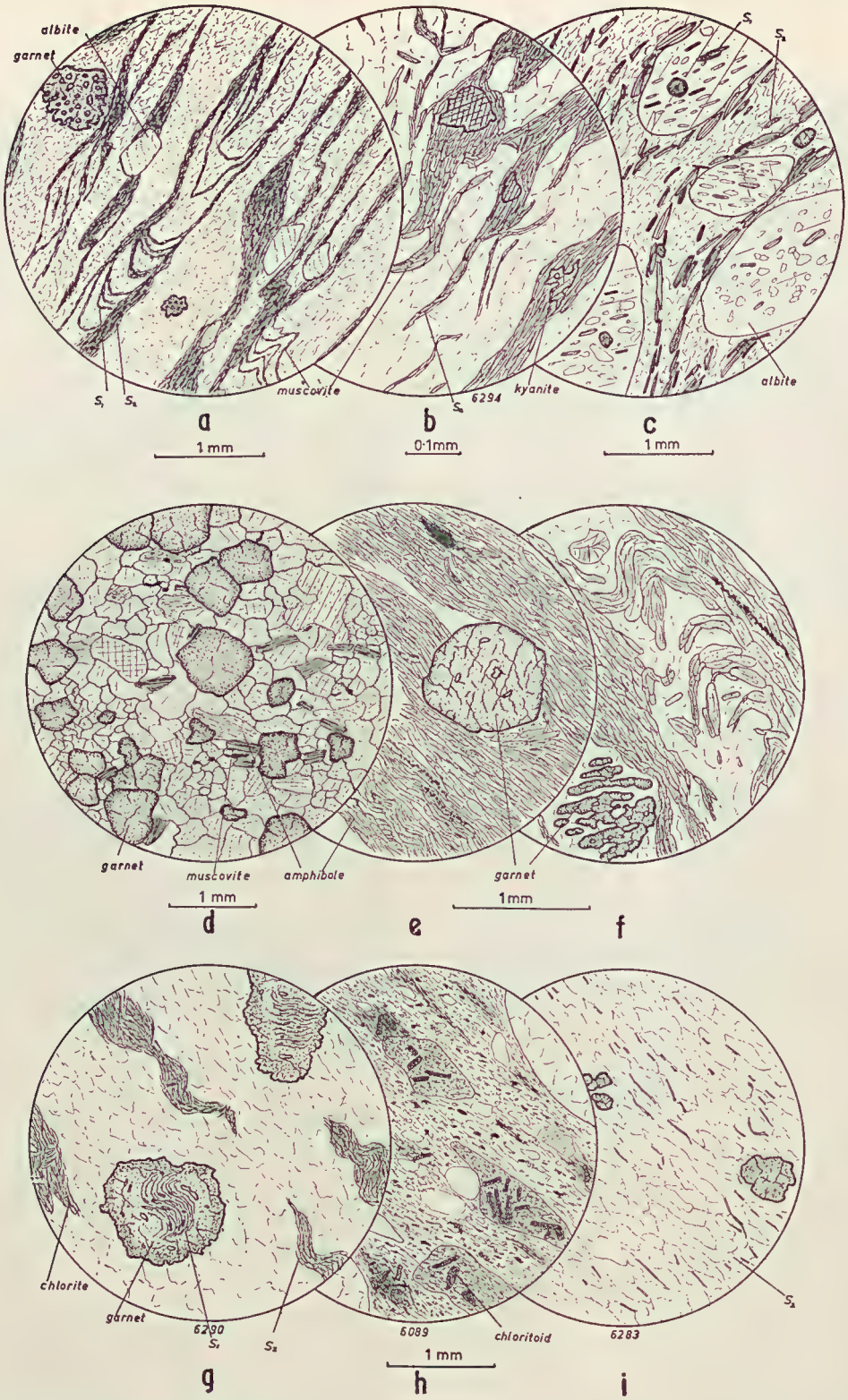
Specimen No. 6333 from Lake Tahune is rather similar and the rocks near Tahune probably should be included in the Scotchfire Group. This area has not been mapped and is shown in fig. 1 as Mary Group. In thin section the rock is fine-grained and strongly foliated. The foliation (S_2) is produced by the parallelism of warped and twisted muscovite flakes and also by the elongation of quartz and dolomite crystals. A few small relics of folds (of S_1) are present between the planes of the major foliation.

CONGLOMERATE (Lachlan)

Regionally metamorphosed conglomerate outcrops on the Lightning Plains where the formation was first recognized by McKellar and informally named the Lachlan Conglomerate. It overlies Scotchfire schist and is itself overlain (probably unconformably) by the Jane Dolomite and is regarded as a formation of the Scotchfire Group. Wells (1957) also found this formation between the Scotchfire and the Jane further to the east. Typical specimens include 7087, 6354 and 6397. The conglomerate (e.g. 7087) is a grey rock consisting of angular to rounded quartz and quartzite fragments up to

	F_1			F_2		F_3	
	Pre-tectonic	Syn-tectonic	Post-tectonic	Syn-tectonic	Post-tectonic	Syn-tectonic	Post-tectonic
muscovite		———		———			
chlorite		———		———	———		
dolomite		?	?	——— ? ———	———	——— ? ———	———
S produced		S_1		S_2		S_3	
S folded				S_1		S_1 S_2	

Chronology of crystallization and deformation of Scotchfire Group calc-schist.



5. Textures of (chiefly) Franklin Group rocks:
   (*a*) garnet-mica schist with S_1 and S_2.
   (*b*) kyanite in muscovite schist.
   (*c*) albite-muscovite schist with S_1 enclosed in albite.
   (*d*) eclogite, Lyell Highway. Chiefly omphacite and garnet.
   (*e*) normal amphibolite.
   (*f*) foliated amphibolite.
   (*g*) snowball garnet (syntectonic and posttectonic to F_1) in schist with foliation S_2.
   (*h*) chloritoid in Lachlan Conglomerate (Scotchfire Group).
   (*i*) garnet-mica quartzite.

several inches in length in a moderately foliated matrix. Under the microscope many of the original clastic features of the rock are visible (fig. 5). The larger quartzite fragments may have been recrystallized but show no evidence of change of external form; most of the sand-size quartz particles are distinctly elongate; originally argillaceous fragments have been strongly drawn out into lenses or whisps; the matrix has been recrystallized and consists of quartz, parallel sericite flakes, a little chlorite and abundant haematite. The most important metamorphic mineral is chloritoid which occurs as small poikiloblastic laths generally about .6 mm. x .1 mm. but with some up to 1 mm. long. It is pleochroic from green to mauve to pale yellow and displays irregular polysynthetic twinning. The chloritoid is restricted to the pelitic fragments and part of the matrix. It shows no preferred orientation and is commonly oblique to the foliation and is posttectonic (to S_1?).

The rock was originally a very poorly sorted conglomerate somewhat akin to the paraconglomerate of Pettijohn (1957). The abundance of haematite is reflected in the high Fe_2O_3 (Table I). Turner and Verhoogen (1960, p. 533) state that chloritoid is restricted to rocks high in FeO and Al_2O_3 but low in K_2O; the bulk composition of this rock is not notable in these respects but the chloritoid is clearly restricted to certain parts of the rock which may have the appropriate composition.

No. 7087 from Thirkell Creek is somewhat similar except that chloritoid is more evenly distributed throughout the matrix. The larger clastic fragments behaved rigidly during deformation and have pressure shadows. Many of the smaller grains also have pressure shadows but some are strongly elongate parallel to the foliation. The quartz is strongly undulose and some grains have pronounced deformation lamellae.

Specimen No. 6337 does not contain chloritoid but has abundant chlorite.

Strongly sheared sub-greywacke sandstones are associated with the conglomerate. The intergranular boundaries between the quartz crystals in some of the quartzite fragments contain a film of haematite and it appears as if migration of the abundant haematite in the matrix has taken place.

SCHIST-QUARTZITE ASSEMBLAGE

A thick belt of mica schist and quartzite forms an arc from Junction Peak in the north-east, through the Raglan Range, and south along the Franklin River to the Twelvetrees Range in the south-west.

Similar garnetiferous mica schists and associated rocks occur on the Mary Creek Plain and at Algonkian Mountain. They appear to overlie rocks of the Quartzite-Phyllite assemblage in some places and to underlie them in others but the structural relations are complex and are discussed later.

The most extensive and best known rocks are those of the Franklin Group.

FRANKLIN GROUP

The Group was defined by Spry (1957) and the total apparent thickness varies from 1000 ft. at Twelvetrees Range to over 10,000 ft. south of the Raglan Range. Detailed mapping at the Raglan Range (Gee, 1962) shows that isoclinal folds ranging from microscopic dimensions to over 2 miles from hinge to hinge, with axes plunging flatly to the west, are responsible for the great apparent thickness.

The Franklin Group consists of a variety of schists with quartzites and minor amphibolites. The minerals present are almandine, muscovite, biotite, quartz, albite, chlorite, actinolite, rare kyanite and pyroxene and accessory tourmaline, rutile, zircon, magnetic, pyrite and zoisite.

Schists

Mica schists are the dominant rock type in the Franklin Group; they show a considerable variety of textures and allow detailed chronological analysis. Important varieties are muscovite schists, knotted albite schists, garnet-muscovite schists, fine-grained dark bi-mica schists, coarse schists or gneisses, and graphitic phyllites.

Muscovite and quartz are ubiquitous; garnet, chlorite and albite are very common; biotite is uncommon and kyanite is rare. The garnet in the schists is almandine. It has an R.I. of $1.801 \pm .001$ and from x-ray data the cell size is 11.55 A. The cell size is a little greater than the figure of 11.518 A (Fleischer, 1937) or 11.526 A (Skinner, 1956) for pure almandine but the proportion of pyrope, grossular or spessaritite appears to be small.

The muscovite is optically negative and measurements of 2V range from 33° to 38°. The x-ray data compare favourably with muscovite but not with paragonite.

Chlorite is present in two forms. The apparent primary form which is aligned along the major foliation is pale yellowish green, non-pleochroic, has a + ve 2V of about 10° and a low birefringence (about 0.008). It is probably a magnesian prochlorite. The secondary chlorite clearly replaces garnet; it shows anomalous blue interference colours and is uniaxial positive. It resembles penninite.

Fig. 5g is of garnet-chlorite-quartz schist No. 6290 with a complex structure. This rock is dark-coloured and knotted without any obvious foliation. In thin section it is seen to be composed of large garnet porphyroblast set in quartz and separated by layers of chlorite. Pyrite is accessory. Some of the chlorite is secondary but much of it appears to be primary. The garnet crystals are notable because of the strong snowball structure but most crystals have an S-shaped core and a massive rim with some crystal faces; this suggests syntectonic growth for the cores and crystallization continuing into the posttectonic stage for the outer parts.

A chemical analysis (Table I) of No. 6290 shows that the rock has moderate silica and alumina, low alkalies and lime but high ferrous iron and magnesia. The garnet is probably almandine and thus the chlorite is probably rich in magnesia; Turner and Verhoogen (1960, p. 539) and Yoder (1952) indicate that almandine and magnesian chlorite may be stable together and this may explain

their common association in the Franklin Group schists although fabric studies suggest that the garnet and chlorite may have formed at different times and that the garnet may have been metastable at the time of formation of the chlorite.

Specimen 6326 consists of large garnet porphyroblasts set in a matrix of contorted chlorite which wraps around the garnet and has formed later.

Many Franklin Group schists are fine-grained with two foliations (S_0 or S_1 and S_2) visible macroscopically, and two (S_1 and S_2) visible microscopically. They consist of quartz, muscovite, albite, garnet, biotite and chlorite. The major foliation S_2 is marked by thin, irregular layers rich in muscovite; the older foliation S_1 occurs as oblique lines of mica flakes, single micas or remnants of fold crests between the layers of S_2 (fig. 5). The muscovite which outlines S_1 is small and twisted and probably syntectonic to F_1; some small albites contain rotational structures and are syntectonic to S_1, others are posttectonic to S_1 (albite is discussed in detail in the albite-rich schist following). Garnet is mostly posttectonic to S_1. Garnet, albite and the S_1 micas are pretectonic to S_2; the S_1 micas are twisted and the S_2 micas are larger and wrap around the albite and garnet. The chlorite mostly forms layers in S_2 and is syntectonic to it although some randomly disposed flakes are posttectonic to S_2.

Although albite occurs in most of the schists, it is particularly abundant in some coarse, knotted albite schists. These are light coloured rocks with albite porphyroblasts up to 1 cm. across and consisting of quartz, muscovite, albite, garnet, biotite and chlorite. Examples are 6291, 6323, 6324, 6751, 6884, 6799 and 6842.

Albite is important as a chronological indicator and occurs in two forms which differ in size, type of inclusions and twinning. The smaller albites tend to be untwinned and contain helicitic folds outlined by tiny opaque granules. They are posttectonic to the oldest structure (S_1) and it is possible that the S_i is actually bedding (S_0). Similar-sized albites show true rotational structure and are syntectonic to S_1.

The large albite crystals which form porphyroblasts up to 1 cm. across are commonly twinned, the twinning being either simple or multiple. The crystals contain abundant large inclusions of quartz, muscovite and garnet in straight or slightly curved lines giving helicitic structure in which S_i (S-internal, the surface within the crystals, as opposed to S_e, S-external, the surface outside) are discordant with S_e (S_2). This is interpreted as being due to the posttectonic crystallization of albite which enveloped a metamorphic foliation differing from that enclosed by the small albites. It is a foliation older than S_2 and is taken to be S_1 which is normally recognized as remnants between the layers of S_2.

Garnet is also present in several different forms and thus is also a useful chronological indicator. Most notable are the syntectonic snowball garnets, some of which have posttectonic massive rims. Others have been fragmented and resemble the "rodded" garnets of Bailey (1923, p. 328); other evidence of pretectonic crystallization are pressure fringes and layers of muscovite wrapping around the garnet. The major foliation (S_2) wraps around the albite and garnet, and the weaker older one (S_1), is preserved mainly within old porphyroblasts.

The large albite crystals are posttectonic to F_1 and pretectonic to F_2, because they are shattered, muscovite of S_2 wraps around them, and S_i is enclosed as S_i. Albite encloses small idioblastic crystals of garnet some of which have rotational structure and are thus syntectonic to F_1, and other are massive so that they are posttectonic to F_1 but earlier than the albite.

Muscovite laths and quartz blebs which delineate S_1 in the albites are syntectonic to F_1, but both minerals are elongate along S_2 and are also syntectonic to F_2. Coarse muscovite also forms posttectonically to S_2; it grows mimetically along S_2 and buts against the old albite crystals.

The relations of crystallization and deformation can be summarized thus:

	F_1			F_2	
Mineral	Pre-	Syn-tectonic	Post-	Syn-tectonc	Post-
quartz		———		———	———
muscovite		———		———	———
biotite		———		———	
garnet	———	———	———		
albite		— — —	———		
chlorite				———	———
S produced		S_0	S_1	S_2	
S folded		S_0		S_0, S_1	

Chronology of crystallization and deformation of Franklin Group albite schist.

Biotite occurs as ragged laths along S_2 and was formed simultaneously with the S_2 syntectonic muscovite. In most specimens it is notable by its absence along S_1 and within the albite crystals, but it does occur in some specimens.

Chlorite is abundant in some schists. It is not found along S_1 but is syntectonic to S_2, thus biotite and chlorite appear to have been formed simultaneously but not garnet and chlorite. Some chlorite has replaced garnet as randomly oriented flakes and is thus posttectonic to F_2. The two varieties differ in composition.

Albite crystallized in the schists in the quiet period following the first deformation phase while the temperature was still elevated; the restriction of the growth of albite to one stage in the schists suggests soda-metasomatism posttectonically to F_1. The origin of similar albite has been a source of controversy as to whether it was primary or has been introduced, and consequently the albite in the Franklin Group must be investigated. Similar albite has been described from the Dalradian schists of Scotland and Ireland and from the Otago Schists of New Zealand (Hutton, 1940; Turner and Hutton, 1941).

Despite considerable study of the albite in the Dalradian schists, the origin is debatable. Clough (1897) considered that the feldspar may have been due to "impregnation"; Cunningham-Craig (1904) and Bailey (1923) believed that the albite was an original contituent of the sediments; McCallien (1929) preferred a metasomatic origin but a later paper with Bailey (Bailey and McCallien, 1934) returned to a non-metasomatic view. Reynolds (1942) put a strong case for metasomatism along the core of the Carrick Castle fold but it was largely based on circumstantial evidence. Jones (1960) came to similar conclusions.

Most of the arguments for a metasomatic origin are not conclusive, the strongest being that the soda content of the schists is higher than that of known sediments. Reynolds (1942) described schists containing 56% albite and 4.2% soda. The proportion of soda (Table I) in the Franklin Group schists is just under 2% which is less than that of Reynolds' "normal biotite schist" and well within the range of common sediments. Thus there is no evidence at present to indicate that the albite in the Franklin schists was other than an original constituent of the sediments.

The chemical analysis of the albite schists show that the proportion of soda is not high, being only a little above that in the garnet schists. Lime is low as in most of the Tasmanian Precambrian schists and potash is high. It is difficult to estimate the exact nature of the original sediment but it was probably a quartz-siltstone. The analysis is similar in some respects to a greywacke but differs in that potash exceeds soda, thus suggesting a mature sediment. The degree of oxidation of the iron is low suggesting a lack of chemical weathering of the sediments but may be more a reflection of metamorphic conditions.

Kyanite is rare in Tasmanian Precambrian rocks, but occurs together with muscovite, chlorite and quartz in specimen No. 6298. The rock is light-coloured and coarse-grained. In thin section it consists mainly of quartz with layers of muscovite and chlorite giving a single irregular foliation. Tourmaline and rutile are accessories. It is not possible to determine the sequence of crystallization events with any certainty. The last deformational phase folded the foliation and made the quartz undulose but was not accompanied by crystal growth; it was presumably the F_3 of adjacent rocks. Muscovite and chlorite are interleaved and were presumably formed simultaneously, but the muscovite has the coarseness generally associated with growth posttectonically to F_2. The kyanite forms skeletal crystals enveloped in layers of coarse muscovite but some small micas wrap around it. By analogy with similar textures in albite schists it is probable that kyanite formed posttectonically to F_1 with the majority of the muscovite posttectonic to F_2.

Quartzites

White, platy, and saccharoidal quartzites are prominent in the Franklin Group in the Raglan Range, near the Franklin River, south-west of Frenchman's Cap, and in the quarries on the Lyell Highway about 25 miles from Queenstown.

The quartzites generally contain muscovite and some also contain garnet, biotite, haematite and accessory tourmaline, rutile, apatite and zircon. They vary from platy to massive, and from fine-grained to saccharoidal. A compositional banding is probably bedding (S_0); a tectonic foliation S_1 is commonly parallel, or almost parallel, to S_0 and curves around the hinges of folds; a later axial-surface foliation S_2 is parallel to, and indistinguishable from, S_1 and S_0 on the limbs of the isoclinal folds but cuts across them in the hinge zones. Intersections of S_0 and S_1, S_0 and S_2, S_1 and S_2, give 3 lineations (L_1 and L_2) which are parallel to the minor folds (F_2) although divergences in direction of up to 10° are not uncommon. Lineation due to rodding, mullions, corrugations, ribs, and lines of elongate mica are at least partly related to F_1 (i.e., are L_1) and thus may not be parallel to F_2 folds although it appears that F_1 and F_2 axes were very similar in direction.

In thin section the quartzites commonly consist of quartz grains which are flat in the plane of major foliation and elongate parallel to the lineation. The foliation is marked by parallel muscovite flakes.

Petrofabric diagrams of the quartzites will be published elsewhere. The mica has a strong degree of preferred orientation and marks a single foliation (S_2). The quartz shows up to 9% maxima in a well developed girdle; this appears to be a normal R-tectonic with a girdle normal to the lineation but actually the girdle is at 70° and the fabric is triclinic rather than monoclinic.

Petrofabric analysis of a recumbent isoclinal fold in quartzite and schist by Gee (1962) shows that the main foliation is independent of the axial surface and curves around the fold; this tectonic surface is S_1 and is parallel or nearly parallel to S_0. No axial surface is shown by the micas in the quartzite in this particular fold but it occurs in others. The quartz fabric is homogeneous throughout the fold and is not "unrollable"; it is thus related to F_2 (S_2).

Some quartzites contain a little garnet and biotite, others are rich in haematite, e.g., nos. 6260 and 6264. These are fine-grained, banded and knotted rocks, dark in colour. They consist chiefly of quartz and haematite; some iron oxide pseudomorphs garnet but in places has replaced quartz. Patches of very fine-grained chlorite occur along some quartz boundaries and quartz appears to have been replaced first by chlorite then by haematite. The processes are post-metamorphic and may be due to weathering.

The garnet relics are curved and web-like indicating syntectonic crystallization but the single irregular foliation S_e is discordant with S_1. It appears likely that quartz, garnet and at least some muscovite formed syntectonically to F_1 but that the foliation was formed (at least partly) in F_2 (i.e., is S_2).

METAMORPHOSED IGNEOUS ROCKS

Various kinds of amphibolites within the Franklin and Joyce Groups have been referred to by Spry (1957) as the Older Basic Igneous Group and are considered to be regionally metamorphosed basic to ultrabasic igneous rocks.

Boudins a few feet wide in schists on the Raglan Range are coated by a thin film of milky quartz. Mather (1955), McLeod (1956) and McKellar (pers. comm.) report that they form small discordant bodies.

The mineralogy of the amphibolites is simple and is congruent with that of the enclosing schists. Garnet, actinolite, biotite, chlorite, albite, quartz, zoisite and epidote are the major minerals with accessory sphene, rutile, magnetite and zircon. The textures are complex and are similar to those of the schists although the uniform nature of the original igneous rocks prevents a detailed recognition of the history. The amphibolites contain one main foliation but show evidence of three separate deformational phases.

In specimens such as 6755 and 6753, an original texture composed of coarse actinolite and garnet has been partly replaced by a new foliated texture of fine-grained actinolite, chlorite, albite, zoisite and rutile. The large pale-green actinolite crystals are undulose, fragmented and rimmed with small amphibole crystals and are pretectonic to the existing foliation. The amphibole has a $Z \wedge c$ of 20° and a 2V negative of 75°. Garnets are fragmented and are wrapped around by small amphiboles and are thus similar in age to the large amphiboles. Many garnets contain a pair of fractures at about 60° to each other and these are regarded as very late congugate shears. The foliation is produced by sub-parallel actinolite prisms, elongate quartz and granules of epidote or zoisite. Some of the small actinolite crystals are syntectonic to the foliation but most are posttectonic and have either grown mimetically parallel to the foliation or are randomly disposed. Much of the small actinolite wraps around the garnet which is older but the late posttectonic amphibole buts against the garnet. A blue-green tint which is restricted to the amphibole in contact with garnet shows that the garnet is older. Accessory rutile occurs as inclusions in all minerals and was one of the first minerals to crystallize.

Other amphibolites differ by containing biotite but no coarse amphibole. The oldest mineral is garnet as abundant porphyroblasts which are massive and well-formed in some specimens, fragmented in others, and have rotational structures in others. The garnet is either syntectonic with posttectonic rims or is entirely posttectonic to an early phase of deformation (F_1). Fractures are filled with quartz, biotite, actinolite, albite or chlorite. Biotite forms large rusty brown, twisted crystals which wrap around the garnet and are parallel to the foliation. These are pretectonic to F_2. The actinolite is pale-green and forms strings, bands or masses of matted crystals wrapping around the garnet. Amphibole, which is fresh and orientated

	F_1			F_2	
	Pre-	Syn-tectonic	Post-	Syn-tectonic	Post-
actinolite		— ? —	———	———	———
garnet		———	———		
biotite		———	— ? —	?	
albite		?	———	?	———
quartz			———	———	
calcite				———	———
chlorite				———	———
S produced		S_1		S_2	
S folded				S_1	

Chronology of crystallization and deformation of Franklin Group amphibolite.

obliquely to the foliation, is posttectonic to F_2. Albite occurs in several forms. Large, fractured and sericitized crystals (e.g., in 6883) are very old (pretectonic to all deformation) and might either be early metamorphic crystals or original phenocrysts. Small shattered and sericitized crystals of albite appear to be of similar age to the garnets; some contain helicitic structure representing the oldest recognizable foliation S_1. Small irregularly shaped fresh albites with S_i concordant with S_e are posttectonic to S_2.

The amphibolites are rather basic in composition and some specimens such as 6744, which consists of 60% actinolite, 30% garnet, and the remainder chlorite, albite, zoisite and quartz, may have been ultrabasic. Other specimens resemble basic rocks and contain about 30% of albite. A massive amphibolite (30132) from the Raglan Range consists of amphibole 64%, garnet 20%, biotite 2%, ilmenite 4%, sphene 1%, and apatite 1%.

The analysis (Table II) is similar to that of other Tasmanian Precambrian amphibolites from the Forth River and Port Davey. The rock was apparently originally a basic igneous rock but differs mainly in its lower silica and alkali content. The soda and potash contents are closer to those of an ultrabasic rock and it seems likely that some alkali loss accompanied metamorphism. Albite is common in veins in the amphibolite.

The amphibolites were first metamorphosed to coarse, weakly foliated and banded rocks rich in actinolite and garnet but a second deformational stage resulted in a reduction of grain-size, contortion of early planar structures and produced a poorly foliated structure. The evolution of fabric is similar in many respects to that of the massive quartzites in the Mary Group.

An actinolite schist (No. 30132) of uncertain affinities is interlayered with normal mica schists at the Raglan Range (Gee, 1962). It is foliated and consists of albite, biotite, quartz, amphibole, zoisite, sphene, apatite and ilmenite. A chemical analysis is given in Table II. It is midway in composition between the normal schists and the amphibolites.

Eclogite

A pyroxene-garnet-amphibole rock, previously referred to by Spry (1957) as a pyroxene amphibolite has been shown to be related to the eclogites (Spry, in press). An analysis is given in Table II.

JOYCE GROUP

The Joyce Group was defined by Spry (1957) and was shown to resemble the Franklin Group. Schists such as 6244 and 6245 are similar to garnet-muscovite-schists described previously from the Franklin Group. No. 6892 is a coarse muscovite-biotite-garnet schist with abundant porphyroblasts of albite which are posttectonic to S_1 which is preserved only as S_i and pretectonic to S_2 which is outlined by muscovite and biotite. The mineral paragenesis is identical with that given for specimen 6323 earlier. No. 6887 is an eclogitic rock from the Joyce Group at Mary Creek Plain and is identical with that from the Franklin Group on the Lyell Highway mentioned earlier.

Some very coarse muscovite schists with porphyroblasts of garnet a quarter of an inch across outcrop on the Mary Creek Plain. Muscovite-quartzites with a strong foliation and lineation and tight isoclinal folds also occur there.

ALGONKIAN MOUNTAIN GROUP

Wells (1957) named the garnet-mica schists around Algonkian Mount (just east of Warnes Lookout) the Algonkian Group. They are referred to here as the Algonkian Mountain Group to avoid ambiguity.

Dark greenish-grey, glossy mica schists such as 6440 are typical. In thin section they are fine-grained schistose rocks consisting chiefly of quartz and muscovite with small porphyroblasts of garnet, albite, a little chlorite, abundant iron ore, tourmaline and zircon. Some of the partially chloritized garnets have " snowball " structure and many albite crystals contain helicitic structure.

No. 6434 is a fine-grained rock consisting chiefly of quartz and muscovite with lesser biotite and albite (with helicitic structure). The structure is very complex and an older, very contorted S-surface can be seen to be partially obliterated by a later imperfectly developed foliation.

The similarity in composition and deformational history between the schists of Algonkian Mountain and those of the Franklin and Joyce Groups is very strong and is seen particularly in specimens 6436, 6437, 6440, 6441 and 6448. The Algonkian Group outcrops east of the south-eastern corner of the map in fig. 1, and thus is not shown. Its structural relationships are not known and no attempt will be made to fit it into the general structural or stratigraphic interpretation.

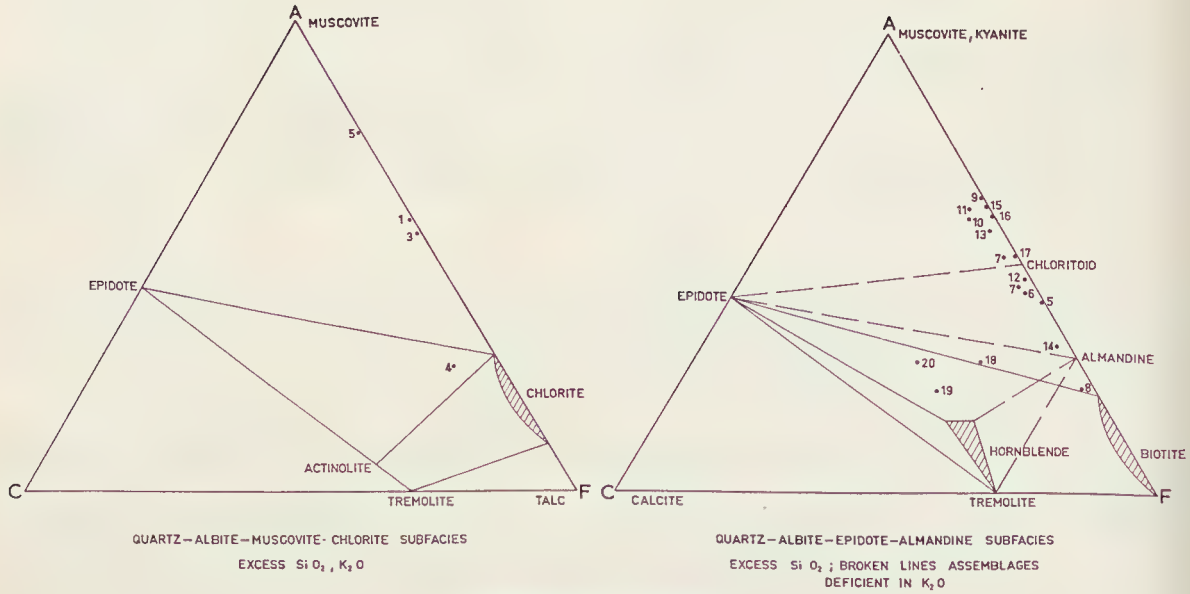
METAMORPHIC PETROLOGY

In terms of the facies classification of Turner and Verhoogen (1960) all rocks belong to the Greenschist Facies. The Mary, Scotchfire and Fincham Groups belong to the quartz-albite-muscovite-chlorite sub-facies whereas the Franklin and Joyce Groups belong to the quartz-albite-epidote-almandine sub-facies.

The rocks belonging to the two sub-facies are intimately related structurally (figs. 1 and 2) and two main problems have been recognized (Spry, 1957, 1962).

(1) Whether or not the rocks of the Franklin and Joyce Groups really differ in metamorphic grade from those of the Mary, Scotchfire and Fincham Groups.

(2) The reasons why the sub-facies boundaries coincide with the lithological boundaries.



GREENSCHIST FACIES

6. Facies classification of metamorphic rocks from the Frenchmans Cap area. Numbers refer to analyses in Table.

METAMORPHIC GRADE OF THE FRANKLIN AND JOYCE SCHISTS

It is difficult to state the exact position of schists from the Franklin and Joyce Groups in the Facies Classification. This is partly because of apparently anomalous associations such as garnet and chlorite or kyanite and albite and partly because the metamorphism consisted of two episodes (F_1 and F_2) which differed in intensity. In general, the association of almandine garnet with albite in rocks rich in muscovite and quartz is typical of the lower part of the garnet zone of regional metamorphism (quartz-albite-epidote-almandine sub-facies) and this is the most probable classification for the schists for the F_1 episode. The occurrence of kyanite (albeit uncommon) the coarseness of grain and the association with eclogite however, suggest that perhaps some of the rocks are of higher grade. The schists are so deficient in lime that a more-calcic plagioclase than albite probably would not occur even at high grades. Albite however, occurs in the amphibolites which are enclosed by schists and this suggests that conditions were appropriate for albite not oligoclase but the amphibolites are comparatively uncommon, and occur as small outcrops, commonly some miles apart.

The status of kyanite as an index of metamorphic grade at Frenchman's Cap is not clear. Ramberg (1953, p. 144) stated the commonly held view that kyanite should not be present as a stable mineral in the Greenchist Facies but Turner and Verhoogen (1960, p. 539) consider kyanite to be stable in this Facies. In view of the complexity of paragenesis at Frenchman's Cap, it is quite possible that kyanite was not a stable mineral.

The common occurrence here of chlorite in garnetiferous schists is not yet understood and must await work on the exact compositions of the two minerals. Study of the chronology of crystallization indicates that garnet formed at an early stage (F_1) and chlorite at a later stage (F_2) but no evidence exists to indicate that the most abundant chlorite outlining S_2 is not in equilibrium with the garnet. Very late chlorite partially replaces garnet, but this is a different variety. It is possible that garnet and kyanite persisted as metastable relics through the later low grade metamorphic phase but a considerable body of evidence indicates that overlap exists between the stability fields of certain garnets and chlorites (Harker, 1932, p. 217; Yoder, 1962; Turner and Verhoogen, 1960, p. 339).

The first stage (F_1) in the metamorphism produced the assemblage quartz-muscovite-biotite-garnet-albite (kyanite) in the schists and the second stage (F_2) produced quartz-muscovite-chlorite. The mineralogy of the quartzites is similar to that of the schists; quartz-muscovite-biotite-garnet at the first stage and quartz-muscovite-chlorite at the second.

The mineralogy of the amphibolites is compatible; actinolite-garnet-biotite-albite during F_1 and actinolite-chlorite-albite during F_2. The amphibole appears to be a pale actinolite rather than the hornblende expected in garnetiferous amphibolites. Many of the amphibolites are rich in mafic minerals and lack feldspar suggesting that they have been derived from ultrabasic igneous rocks.

METAMORPHIC GRADE OF THE MARY, FINCHAM AND SCOTCHFIRE GROUPS

Most of the Mary Group phyllites contain only the insensitive pair quartz and muscovite but the assemblage quartz-muscovite-chlorite occurs in some Mary, Fincham and Scotchfire phyllites. The last Group also contains dolomite, chloritoid, actinolite and zoisite. Feldspar is almost entirely absent. The mineral assemblages appear to have been constant in all these rocks though both F_1 and F_2 and indicate the quartz-albite-muscovite-chlorite sub-facies of the Greenschist Facies.

RELATIVE METAMORPHIC GRADES

The Franklin and Joyce Groups are mainly distinguished from the Mary, Scotchfire and Fincham Groups by their coarser grainsize, greater degree of recrystallization and the presence of garnet and biotite. This is sufficient to indicate different intensities of metamorphism only if the rocks are of similar composition. The Franklin and Joyce Groups are dominantly meta-pelites with minor quartzites, the Mary and Fincham are mainly quartzite and the Scotchfire is mainly pelitic. Analyses in Table I show that the chemical compositions of a Scotchfire phyllite, various Franklin schists and a Mary phyllite are not sufficiently different to account for the difference in mineralogical composition. It is concluded that the difference is metamorphic grade is real.

Field-mapping shows that adjacent rock units such as the dominantly quartzite Mary Group and the schist-rich Franklin Group can be delineated and that bedding, where recognizable, seems to be generally parallel to the junction between the major units. The apparent stratigraphic boundaries are also metamorphic boundaries. Detailed work by Gee (1962) indicates discordance between Franklin and Mary structures right at the contact and also the presence of a thin layer of quartz-albite-muscovite-biotite sub-facies between them.

The distribution is revealed as even more unusual than it appears on the map when the third dimension is considered. Remnants of S_0 and S_1 in the Joyce, Mary, Franklin and Fincham Groups all dip in the same direction along certain lines of section. This suggests (Spry, 1957) that the higher grade Franklin Group is sandwiched between the lower grade Mary and Fincham Groups.

The best explanation seems to be that the Mary and Fincham Groups are equivalent as are the Franklin and Joyce. Similarities in fabric evolution appear to preclude the possibility of an unconformity between the lower and higher grade assemblages such that the former were only affected by the lower grade F_2 and the latter by the higher grade F_1 as well as F_2. Field study of the contacts between rocks belonging to the two assemblages, also rules out the possibility of unconformity.

STRATIGRAPHIC CONSIDERATIONS

It is not possible to establish a stratigraphic succession in this area, nor to correlate confidently between Groups. The most obvious similarity is between the Franklin and Joyce Groups but the main problem is that the less altered Mary Group appears to lie between them. The Joyce Group passes beneath the Franklin Group between Mt. Mary and the Raglan Range. The Joyce Group dips beneath the Mary Group at the eastern end of the Mary Antiform (Spry, 1957) but further west across the Collingwood Synform, the rocks which appear to pass beneath the Mary Group are continuous with the Franklin Group (Spry and Zimmerman, 1959). The latter contact was interpreted as a fault but this is uncertain. It seems likely that the Joyce and Franklin Groups are equivalent.

It does not seem possible to correlate between the Joyce, Mary, Franklin and Fincham Groups in the western part of the area and the Scotchfire, Algonkian and Elliot rocks in the eastern part. Spry and Zimmerman (1959) suggested a major structural break (Artists Hill Fault) between them.

It has been considered (Spry, 1957) that the Mary and Fincham Groups might be equivalent because of their topographic expression and general lithological similarity. There are differences, however, which suggest that the Fincham is closer to the Scotchfire. The Fincham Group contains about 65% of phyllite and siliceous phyllite, 25% quartz schist and 10% massive quartzite. The Mary Group contains about 20% phyllite, 45% quartz schist and 35% massive quartzite. The differences might be accounted for by difficulties in terminology between e.g. siliceous phyllite and quartz schist, and also by structural complexities.

The most likely correlations are as follows:

(1) The Franklin, Joyce and Algonkian Groups are the same but are separate from the Mary Group (= Elliot Quartzite) plus the Fincham (= Scotchfire Group).

(2) The Scotchfire Group may overlie the Elliot Quartzite (Wells, 1956) which may be equivalent to the Mary Group which is overlain by the Franklin Group. This suggests that the Scotchfire may be the lower grade equivalent to the Franklin. Gee (1962) observed that the Fincham Group (which resembles the Scotchfire) appeared to pass laterally into the Franklin Group with increase of grade. The Scotchfire and Franklin are somewhat similar but the Franklin contains abundant albite which is very rare in the Scotchfire, and the Scotchfire contains a number of dolomites which have not been found in the Franklin.

Correlation for the present will be restricted to the western structural unit where possible successions are:

(I)	(II)	(III)
Fincham	Mary=Fincham	Fincham
Franklin	Franklin=Joyce	Franklin=Joyce
Mary		Mary
Joyce		

No positive statements can be made about the stratigraphic sequence because of the lack of facings and the order of the alternatives above may be reversed. Alternative (III) is preferred here, but the major structure given later can accommodate any of the sequences.

Contacts Between Groups

The nature of the contacts between such groups as the Mary and Franklin or the Mary and Joyce are of great importance in solving the structural, stratigraphic and petrological problems of this area, but they are at present poorly understood. They have been interpreted as faulted (McLeod, 1955, pp. 6, 18; Spry, 1957), conformable (Mather, 1955, p. 22), unconformable (Spry, 1957), and as gradational (Mather, 1955, p. 22).

The evidence is as follows:

(1) Joyce-Mary Contact.

The foliation (S_2) of schists in the Joyce Group dips shallowly beneath phyllite at the base of the Mary Group at the eastern end of the Mary Antiform. There is an apparent gradation up the southern spur of Wards Bluff with the orientation of the visible foliation similar in both.

Further west on the Mary Creek Plain, the Joyce schists striking at 75° and dipping steeply north are overlain by basal phyllite of the Mary Group striking at 120° and dipping north at 10°-16°.

(2) Mary-Franklin Contact.

This contact is disturbed by Palaeozic faults in many places but is undisturbed near the junction of the Mary Creek and the Franklin River, about 2 miles N.N.W. of Wards Bluff and between Flat Bluff and the Raglan Range. The contact near the Raglan Range has been studied in most detail (Gee, 1962) and appears to be a metamorphic boundary dislocated by later "sliding" (in the sense of Bailey, 1909, p. 53-4; 1910, p. 593). The basal formation of the Franklin Group is the Governor River Phyllite (Gee, 1962). This overlies phyllites with interbedded thin quartzites of the Mary Group, and the quartzites appear to be discordant at the contact i.e. the contact is oblique to the bedding in the Mary Group. There appears to be complete gradation between Mary Group phyllite (analysis No. 15, Table I) with chlorite, Governor River Phyllite (No. 16) containing biotite, thence into schist (No. 17) containing garnet, over a distance of 600 ft. The grainsize increases from the Mary to the Franklin but is largely due to mimetic crystallization of muscovite, posttectonically to F_2 The The foliation S_1 is prominent in the Mary phyllite but becomes increasingly deformed through the transition into the Franklin Group where S_2 is the dominant foliation.

The analysis of the chronology of deformation and crystallization given earlier shows that the difference in grade between the Mary and Franklin Groups was produced during F_1, but isoclinal folds (up to 2 miles from hinge to hinge) were formed during F_2. In a discussion of the major structure later, it will be suggested that the metamorphic zones (i.e., the Mary, Franklin, Joyce and Fincham Groups) were folded into a very large recumbent fold during F_2 and that the contacts were blurred by F_2 movements.

STRUCTURE

The structures can be divided into two main groups:

1. Precambrian (F_1 and F_2) foliations (S_1, S_2), lineations (L_1, L_2) and folds (F_2).
2. Tabberabberan (Devonian) (F_3) folds faults.

Palaeozoic (Tabberabberan) Structures

The Frenchman's Cap area is part of the Tyennan Geanticline (Carey, 1953) which was a relatively stable region from Late Precambrian to Middle Palaeozoic times. The Geanticline also formed a mass against which the Palaeozoic sediments were folded but the Precambrian rocks were not completely rigid and participated in the folding. It has been shown elsewhere (Spry and Gee, in press) that all of the large scale folds and faults visible in fig. 1 are of Tabberabberan age. Also that "unrolling" the Palaeozoic anticline at the Raglan Range leaves the foliations of the Franklin Group with a few degrees' dip to the west. Thus prior to the Palaeozoic, the Precambrian rocks were sub-horizontal and folded into recumbent isoclinal folds.

The more important Precambrian structures have the following features:

Bedding (S_0). Comparatively undistorted bedding is recognizable in massive quartzites of the Mary Group where it contains ripple marks. The lamination in many of the quartzites and the contacts between thin layers of schist and quartzite may represent bedding which has been transposed in varying degrees.

Foliations. The schists and phyllites contain up to three (S_1, S_2, S_3) mesoscopic and microscopic foliations, but these are developed to different degrees in different rocks.

Phyllites and schists commonly contain two mesoscopic foliations marked by parallel mica flakes and a fracture cleavage (S_3) which may be much younger. The foliation (S_2) is marked by layers of mica flakes and is parallel to the axial surfaces of folds; it cuts across an older crumpled surface (S_1) which is parallel or nearly parallel to a colour banding which may be S_0. S_0 and S_1 have been completely obliterated by mica growth along S_2 and are not visible in the coarser Franklin Group schists.

The foliation in the Franklin quartzites and Mary quartz-schists is differently developed. It is a plane of parting due to parallel muscovite flakes; quartzites lacking mica are very weakly foliated. The foliation is parallel or nearly parallel to compositional banding (S_0) and both have been folded and are cut by a sporadic axial-surface foliation which is identical with S_2 in adjacent schists. The main foliation in the quartzites is S_1 and in most outcrops it is parallel to S_0.

Lineations

Franklin Group quartzites are the most strongly lineated; some Mary, Fincham and Scotchfire quartz schists also have a lineation but many phyllites and schists have none.

The linear structures in Franklin quartzites consist mainly of fine striations on foliation surfaces accompanied by elongation of quartz grains and large mica flakes. It is almost normal to a girdle of quartz optic axes which has been shown to be an F_2 structure so that this lineation is L_2. Other L_2 structures in these quartzites include fold axes and fold mullions in the cores of the larger isoclinal folds. S_2 is weak in most quartzites so that an L_2 formed by intersections of S_2 with S_0 is less common but does appear in the hinge zones of some isoclinal folds.

Some lineations appear to be intersections of S_0 and S_1 and thus are L_1 structures but these are difficult to recognize because S_0 and S_1 are similar in orientation.

Lineation (L_2) in the schists and phyllites is due to crenulations of S_1, to intersections of S_1 and S_2 and to a shredded fibrous appearance. Quartz-rods produce a strong lineation (L_2) in many schists and phyllites. They tend to be particularly abundant in the cores of folds. They vary from slender rods and prisms a metre in length and a centimeter or so in diameter down to irregular lenticular rods a centimeter or so long. Some can be recognized as remnants of quartz veins which have been folded together with S_1.

Lineation in some quartz-schists or quartzites from the Mary Group is due to crenulations of S_0, or intersections of S_0 and S_1 and these may be L_1; crenulations of S_1 are L_2 and L_3 structures. L_1 and L_2 are similar in direction.

Boudinage

Boudins of quartz and quartzite are enclosed in schist and phyllite. Boudins of amphibolite with circular section and unknown length occur in Franklin Group schists (Gee, 1962). All gradations may be seen between discrete quartz rods and quartz boudins, particularly in the cores of folds. The long axes of the boudins and the striations on their surfaces are parallel to the lineation in the enclosing rocks.

Folds

Folds range from microscopic dimensions up to about 2 miles from hinge to hinge. All are attributed to F_2 as S_0 and S_1 are folded and S_2 is the axial surface. No F_1 folds have been recognized. The quartz-fabric in the Franklin quartzites is related to F_2 folds but it is possible that at least part of the fabric in the Mary Group quartzites is related to F_1. Lineations are essentially parallel to fold axes.

Most folds are recumbent and isoclinal. Folds in schist range from irregular crumples and chevron folds to simple similar folds. The latter have strong axial surface foliation with attentuated limbs. Examples have been figured by Spry (1957) and Gee (1962).

Microscopic Symmetry

The mesoscopic fabric is characterized by a lineation which is an axis of rotation normal to a plane of symmetry. Axes of asymmetrical folds, lineation, rods, mullions and boudinage are parallel and constitute a B lineation. The symmetry of F_1 and F_2 structures is basically monoclinic.

Large Scale Precambrian Structure

It has not been possible to recognize the large-scale Precambrian structure by mapping and the problem is made more difficult by the uncertainty of the stratigraphic succession. Field mapping has revealed a series of thick layers (Mary Group, Franklin Group, &c.), separated by surfaces along which there may have been considerable movement. After the Palaeozoic folds are removed the layers undulate with a lineation plunging at 4° towards 290° (Spry and Gee, in press). It is regarded as most probable that the major Precambrian fold axes plunge in the same direction. Following McIntyre (1951), &c., a tectonic profile may be sketched looking down the direction of the lineation. The Devonian folds show as a series of synforms and antiforms and the general structure of the higher part of the profile is similar to that given by Spry (1957) and Spry and Zimmerman (1959).

The most striking lithological similarity in the area is that between the Joyce and Franklin Groups; that between the Mary and Fincham Groups is less close. Several structures were suggested by Spry (1957) to allow correlation of these groups and one of these was by isoclinal folding. A plan and section of such a structure is given in fig. 8 but this kind of structure is considered unlikely for the following reasons:

(1) The subhorizontal axes of the isoclinal folds curve around in plan but the lineation is not disturbed in this way.

(2) The hypothetical fold axes are not parallel to the lineation.

(3) The arrangement of fan folds in the cross section is not a convincing structure.

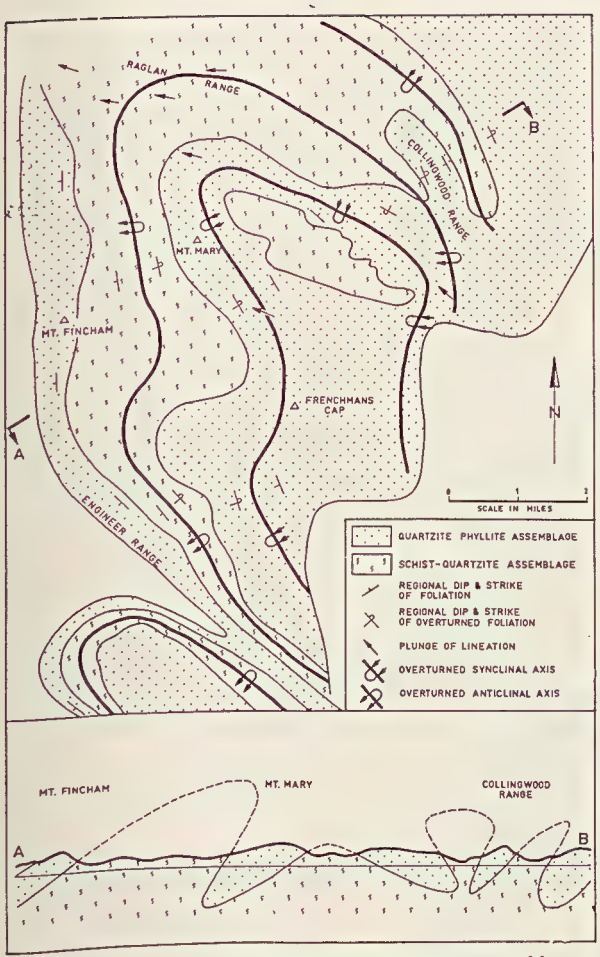
It is postulated that any major structure must have its major tectonic axes parallel to the lineation and that this structure is some kind of large recumbent fold plunging very flatly towards 290°. The kind of structure is not unlike that of McIntyre's (1952) interpretation of Beinn Dronaig and the reasoning follows his.

Following this hypothesis two alternative structures are possible:

(1) Two lithologies are interleaved as the Joyce, Mary, Franklin and Fincham Groups as a series of nappes.

(2) The Joyce is the same as the Franklin Group and the Mary is the same as the Fincham Group, and the two are folded into a series of recumbent folds. As there is no physical continuity between the groups correlated, the closures of the folds would lie outside the area mapped.

7. Profiles across the hypothetical Pillinger fold illustrating possible structural relationships.



8. Fan-fold hypothesis for the Frenchmans Cap area; this an unlikely explanation.

The second alternative is the most reasonable yet found as it is congruent with:

(1) All field observations on the distribution of lithologies.

(2) The style of the minor structures.

(3) The direction of the lineation.

It brings together the apparently different stratigraphic sequences suggested earlier in that the Joyce-Franklin and Mary-Fincham correlations can be made. The Scotchfire is most reasonably regarded as the upper part of the Fincham, but the hypothesis is sufficiently flexible for it to become the lower grade equivalent of the Franklin and Joyce.

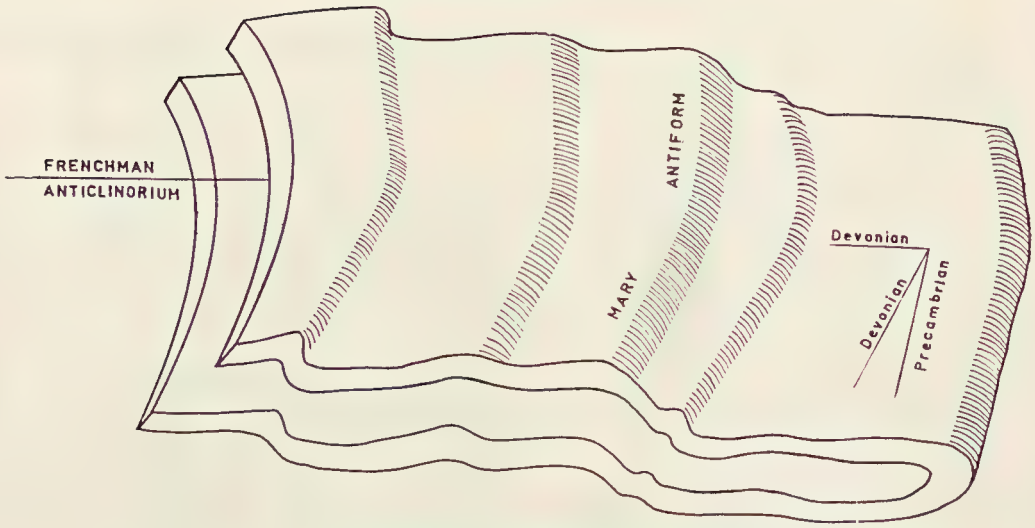
It is impossible to predict much about the size and shape of the larger Precambrian structures but in fig. 7, hypothetical profiles (looking down the lineation) indicate the kind of structure considered likely. This large hypothetical fold is named the Pillinger Fold from its occurrence in the Pillinger Quadrangle. Fig. 9 shows the fold with the Devonian structures superimposed.

TECTONIC EVOLUTION

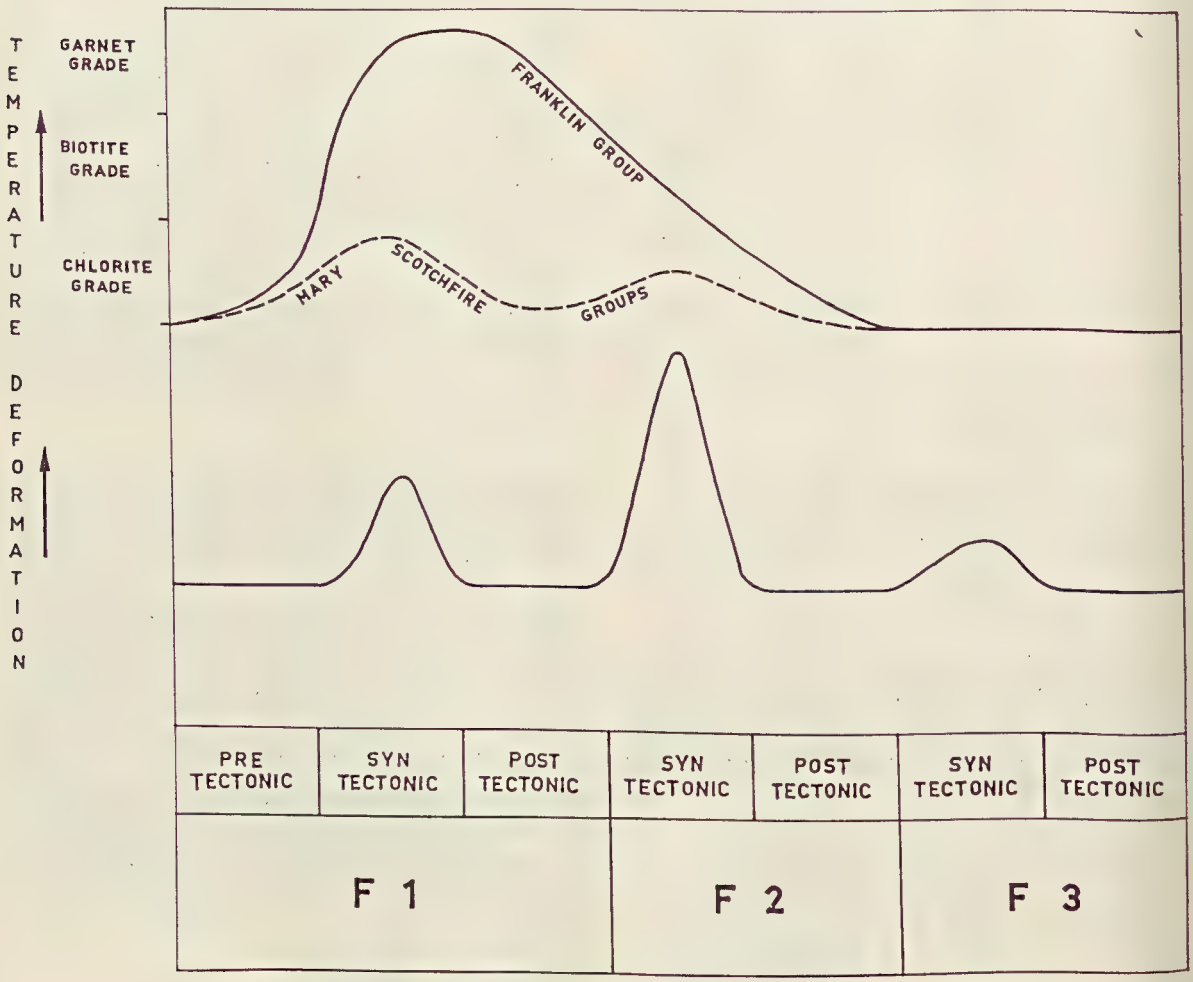
The relations between the formation of the various minerals and the successive stages of deformation are summarized in fig. 10. The main regional metamorphism contained at least two periods of deformation. A third pulse crenulated the rocks and produced a fracture cleavage but was not accompanied by mineral formation.

The first two phases of the metamorphism differed in character. The high-grade minerals (garnet and kyanite) in the Franklin Group were produced during F_1 and the lower grade assemblage (muscovite-biotite-chlorite) was formed during F_2. The Mary and Scotchfire phyllites contain no evidence that the first phase was of higher grade than the second. Albite crystallized abundantly in Franklin schists in the inter-tectonic period but there is no evidence that this was necessarily due to metasomatism. Conditions appropriate for the formation of garnet and kyanite existed in the inter-tectonic period and chlorite probably did not appear until later. The Franklin amphibolites were coarse garnet-actinolite rocks during F_1 but were reduced in grainsize during F_2 with an accompanying lowering of grade as garnet was replaced by chlorite. The massive Mary quartzites are similar to the amphibolites in that they were coarse, granular rocks during F_1 but were granulated during F_2 to give mortar structure. The Franklin quartzites were coarse quartzites in the first phase and some contained garnet; during the second phase the grainsize decreased and chlorite developed. Conditions were such that considerable posttectonic crystallization took place in the Franklin Group rocks after the F_2 phase; muscovite grew in the schists, actinolite in the amphibolites and quartz in the quartzites to obliterate some effects of earlier deformation.

The limited evidence available does not allow mesoscopic distinction between structures produced during F_1 and F_2 stages as no difference in orientation or style have been found. Isoclinal folds range in size from fractions of a millimetre to a kilometre or so across and it is suggested that the major fold is many kilometres across. The small folds belong to F_2 and it is postulated that the hypothetical major folds belongs to this stage also. Thus it is suggested that the temperature peak was reached during F_1 but that most deformation took place in F_2. It is thought that two lithological assemblages originally existed; a quartzitic and a pelitic group. The quartzitic group (Mary, Scotchfire, Fincham) was metamorphosed to chlorite grade and the pelitic group (Franklin, Joyce) to garnet grade during the first stage of metamorphism (F_1). The two lithologies were tightly infolded as a large recumbent fold during the second stage of metamorphism (F_2) and a chlorite grade in all the rocks tended to blur the effects of the first stage.



9. Three-dimensional view of the hypothetical Pillinger fold, refolded by Devonian structuers.



10. Relations between grade of metamorphism and deformation during F_1, F_2 and F_3.

TABLE I

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2	74.32	98.00	71.72	70.72	66.40	29.00	69.28	60.12	75.24	68.00	67.20	73.70	71.60	49.92	68.00	68.00	66.33	58.18
Al_2O_3	12.90	0.62	13.99	10.51	13.63	3.75	15.64	11.60	13.27	17.00	17.67	11.62	14.72	16.76	17.01	15.72	18.21	15.36
Fe_2O_3	0.43	Tr	1.67	0.97	9.44	1.70	0.57	1.00	1.28	1.96	2.30	2.95	1.04	4.81	1.96	0.92	1.46	0.79
FeO	2.69	0.77	1.20	4.91	2.83	0.66	4.61	14.47	1.41	2.54	2.72	3.69	8.84	8.84	2.54	3.02	2.34	5.31
MgO	3.27	nill	2.01	4.91	1.00	14.53	1.48	7.00	0.94	1.16	1.19	2.00	2.56	6.91	1.16	1.43	1.74	6.72
CaO	nil	0.04	0.08	1.52	Tr	18.96	0.68	0.68	0.04	0.60	0.32	0.04	0.16	0.72	0.60	0.32	0.44	5.00
Na_2O	0.44	0.18	0.05	1.29	1.21	0.12	1.93	0.16	1.98	1.31	0.98	0.09	1.71	2.12	1.31	1.18	1.25	1.69
K_2O	3.08	0.24	6.02	1.12	1.59	1.60	3.42	0.32	3.36	3.64	3.47	2.47	3.02	1.61	3.65	3.64	4.23	2.95
H_2O+	2.90	0.18	2.48	2.97	2.13	n.d.	1.96	4.20	1.43	2.93	3.06	2.96	2.94	5.33	2.93	2.79	2.93	2.61
H_2O-	0.20	0.04	0.26	0.18	0.22	0.30	0.10	0.18	0.20	0.19	0.18	0.36	0.14	0.53	0.19	0.12	0.47	0.49
MnO	Tr	Tr	nil	0.07	Tr	0.04	Tr	0.06	0.03	0.02	0.02	0.04	0.02	0.05	0.02	0.02	0.01	0.09
TiO_2	0.35	0.05	0.34	0.44	1.02	0.10	0.45	0.30	0.04	0.69	0.94	0.45	0.69	2.44	0.69	0.78	0.94	0.61
P_2O_5	0.05	TR	0.07	0.11	0.21	0.04	0.05	0.07	0.02	0.06	0.40	0.03	0.05	0.24	0.06	0.06	0.07	0.15
FeS_2																1.29		
SO_3																0.14		
	100.63	100.12	99.89	99.72	99.67	....	100.17	100.16	99.24	100.10	100.45	100.40	101.27	99.23	100.12	99.89	100.47	99.95

1. Phyllite, 6227, Mary Group, Mt. Mary.
2. Quartz schist, 6220, Mary Group, Mt. Mary.
3. Phyllite, 7310, Scotchfire Group, Lyell Highway.
4. Schist, 6372, Scotchfire Group, Lyell Highway.
5. Conglomerate (Lachlan), 7087, Scotchfire Group, Lightning Plains.
6. Dolomite, 6416, Scotchfire Group, Thirkell Creek.
7. Garnet Schist, 6275, Franklin Group, Raglan Range.
8. Garnet Schist, 6290, Franklin Group, Cardigan River.
9. Albite Schist, 6323, Franklin Group, Cardigan River.
10. Coarse garnet-albite schist, 30149, Franklin Group, Raglan River.
11. Mica schist, Franklin Group, Timber Mill, Raglan Range.
12. Chloritized garnet schist, 30125, Franklin Group, Western Raglan Range.
13. Muscovite-chlorite schist, 30150, Franklin Group, Western Raglan Range.
14. Knotted albite schist, 30115, Franklin Group, Raglan Range.
15. Governor Phyllite, Mary-Franklin Transition, Joyce Creek.
16. Governor Phyllite, Mary-Franklin Transition, Joyce Creek.
17. Governor Phyllite, Mary-Franklin Transition, Joyce Creek.
18. Amphibole Schist, Franklin Group, Raglan Range. Analyses, Tas. Dept. Mines.

TABLE II

	1	2
SiO_2	44.78	50.92
Al_2O_3	13.44	16.83
Fe_2O_3	2.41	1.11
FeO	16.22	9.18
MgO	7.01	7.99
CaO	9.12	9.87
Na_2O	1.65	1.15
K_2O	0.47	1.12
H_2O+	1.58	0.96
H_2O-	0.07	0.14
MnO	0.36	0.18
TiO_2	2.81	0.60
P_2O_5	0.40	0.02
	100.32	100.67

1. Amphibolite, Raglan Range, anal. W. St. C. Manson.
2. Eclogite, Lyell Highway, anal. W. St. C. Manson.

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HINSDALITE PSEUDOMORPHOUS AFTER PYROMORPHITE, FROM DUNDAS, TASMANIA

By

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(With two text-figures)

ABSTRACT

Hinsdalite, $PbAl_3(PO_4)(SO_4)(OH)_6$ occurs as pseudomorphs after pyromorphite from the Dundas area. Determination of the mineral was made by the use of X-ray powder diffraction, spectroscopy, chemical spot testing and differential thermal analysis. Hinsdalite crystallizes in the rhombohedral system and the cell constants, $a_{rh} = 6.90$ and $\alpha = 61° 8'$ of the Dundas material agree closely with those of the type material from Colorado. The mineral can be synthesized in the laboratory either from a solution of its constituent ions or by alteration of pyromorphite. The unusual feature of the environment in which hinsdalite forms is the presence of large quantities of aluminium. In the Dundas case it is believed that weathering of eugeosynclinial sediments in the presence of soil waters of low pH and high humic acid content have made the aluminium available.

INTRODUCTION

Largely through the early efforts of Petterd (1910), the Dundas mineral field has earned mineralogical renown for its content of rare, oxidised zone minerals, amongst which the lead chromate, crocoite, is the best known. Investigation of several specimens of pyromorphite from the field has led to the recognition of yet another rare mineral, namely hinsdalite, $PbAl_3(PO_4)(SO_4)(OH)_6$. This mineral is one of a number of rare phosphate-sulphates collectively known as the Beudanite Group (Palache et al, 1951, p 1001). It was originally recognised by Larsen and Scaller (1911) in hydrothermal veins of the Golden Fleece Mine, Hinsdale County, Colorado.

OCCURRENCE

The Dundas hinsdalite occurs as sparse nests of pseudomorphs after the typical green pyromorphite of the Comet and other mines of the Zeehan-Dundas mineral province. Usually the pseudomorphs are solid although some occur merely as thin walled shells of hexagonal outline. Gibbsite is associated with the pyromorphite-hinsdalite assemblage. The occurrence appears to be only the second recorded for the mineral and the first in the oxidised zone, although other members of the Beudanite Group typically form in this environment.

CHEMICAL COMPOSITION

The small amounts of material available did not allow complete analysis to be made. Semi quantitative spectography established the presence of lead and aluminium as dominant metals with silver as a minor constituent. Chemical spot testing indicated the presence of phosphate and sulphate. Strontium, present in the type material, does not occur in that from Dundas.

MINERALOGICAL DATA

The fine grained nature of the pseudomorphs precluded accurate microscopic examination. The material was found to exhibit the anomalous biaxial segments characteristic of the minerals of the Beudantite Group (Figure 1). The mean refractive index was found to be 1.69.

Detailed study was undertaken by means of X-ray powder diffraction using a Philips Model 1050 X-ray Diffractometer. No data were on record for hinsdalite and the Australian Museum kindly donated type material to enable comparison to be made with the Dundas specimens. A check through the A.S.T.M. Card Index showed that there was a good match with the data of Card 2-0683, for plumbogummite, $PbAl_3(PO_4)_2(OH)_5.H_2O$. The diffraction data are given in Table 1. Selected spacings were determined more accurately by means of fixed-count techniques and cell data were computed from these results. The unit cell of hinsdalite is rhombohedral and contains one molecule. For the Colorado material $a_{rh} = 6.88$, $\alpha = 61° 8'$, the cell volume is $236A^3$ and the calculated specific gravity 3.92. For the Dundas material $a_{rh} = 6.90$, $\alpha = 61° 8'$ the cell volume is $238A^3$ and the calculated specific gravity 4.06. The differing values of specific gravity are due to the fact that the Cororado material contains strontium substituting for lead in a molecular proportion of about 1:5. The measured value of 3.65 for the mineral (Palache et al 1951, p 1004) is low and can probably be attributed to the presence of impurities in the sample used for the physical determination. Smith et al (1953) have noted a similar discrepancy in the case of hidalgoite, the arsenate analogue of hinsdalite.

The data of Table 1 show that determination of the minerals concerned on the basis of X-ray powder diffraction alone could be misleading.

Detection of sulphate does not necessarily rule out the possibility of plumbogummite since the ion could be present by contamination. As plumbogummite contains water, differential thermal analysis coupled with X-ray procedures gives a more reliable result than chemical testing. Both hinsdalite and plumbogummite were synthesized from solutions of their constituent ions, and together with Colorado and Dundas hinsdalite, were subjected to differential thermal analysis. The results, shown in Figure 2, indicate that only the curve of plumbogummite contains a strong endothermic peak due to water loss.

MINERAL GENESIS

In the laboratory, formation of hinsdalite is effected by co-precipitation of lead sulphate and aluminium phosphate. With ageing at an elevated temperature this mixed precipitate gradually converts to hinsdalite as is shown by the equation below:—

$$PbSO_4 + 3AlPO_4 + 6H_2O \rightleftharpoons PbAl_3(PO_4)(SO_4)(OH)_6 + 2H_3PO_4$$

At Dundas, the formation of the mineral has been by means of alteration of pyromorphite. Comparison of the formulae of the two minerals shows that chemically only aluminium, sulphate and hydroxyl ions are needed to change pyromorphite into hinsdalite. Refluxing of finely ground pyromorphite with a solution of aluminium sulphate does in fact produce hinsdalite within 24 hours. Since the reaction in nature results in the formation of a pseudomorph it must take place at constant volume.

The volume of the pyromorphite unit cell is $630A^3$ and that of a hexagonal hinsdalite cell (triply primitive) is $708A^3$. The nearest approach to a volume constant reaction occurs when 9 molecules of pyromorphite are replaced by 24 molecules of hinsdalite (a cell ratio of 9:8). The resulting equation for the volume constant conversion is given below:—

$$\underset{\text{Pyromorphite}}{9Pb_5(PO_4)_3Cl} + 72Al_3^+ + 24SO_4^{2-} + 144OH^- (+24Cl^-) \rightleftharpoons \underset{\text{Hinsdalite}}{24PbAl_3(PO_4)(SO_4)(OH)_6} + 21Pb^{2+} + 3PO_4^{3-} + 9Cl^- (+24Cl^-)$$

The bracketed chloride ions in this equation serve no other purpose than the maintaining of electrical neutrality on both sides of the equation. The alteration has been subjected to physico-chemical studies (Baker, 1962) and these show that the proposed reaction results in an overall decrease in the free energy of the system. Such a reaction can thus take place spontaneously as required by the formation of hinsdalite in the oxidised zone of the Dundas mineral deposits.

The unusual condition which must be fulfilled for the formation of hinsdalite in either a hydrothermal or oxidised zone environment is that aluminium must be abundant. It is this condition which surely explains the rarity of the mineral. During differentiation of a magma the bulk of the aluminium is incorporated in the rock forming minerals. Unless the parent magma was unusually rich in aluminium, or that contamination in some way caused it to follow a peculiar differentiation path it is unlikely that this metal would appear as a constituent of the hydrothermal solution. In the weathering process aluminium has low mobility and tends to remain bound in the clay minerals.

The reason for the occurrence of aluminium in the Dundas environment and for its departure from the normal behaviour is not clear. Unfortunately little detail is known of the Dundas mineralization as the mines of the area ceased operations before systematic geological investigations were undertaken. The general environment is one of mineralization along contact zones getween ultrabasic rocks and eugeosynclinal sediments and volcanics. The abundance of aluminium in the environment is clearly shown by the presence of a considerable quantity of gibbsite which is closely associated with the oxidised zone minerals of the area. Since aluminium is generally not incorporated in the mineral assemblages of ultra-basic rocks there remains only the Dundas sediments. Whilst no analyses of typical rocks are available the stratigraphic column consists, in considerable part, of greywackes, tuffs and shales all of which are likely to contain higher than average amounts of aluminium. The soil waters of parts of western Tasmania have pH values as low as 3.5 and they are relatively rich in humic acids. Such waters have a strongly corrosive action on the rocks with which they make contact, and weathering under these conditions could make large quantities of aluminium freely available.

It is of interest to note that Petterd (op. cit. p. 139) has recorded the occurrence of plumbogummite at Zeehan. Some of this material was still available in the collection of The Tasmanian Museum and this institution kindly loaned it for examination. Under the binocular microscope the mineral is seen as an off-white resinous material developing at the expense of brown pyromorphite which coats partially decomposed galena. Thus in this case also the mineral occurs as an alteration product of pyromorphite. The results of mineral synthesis show that both hinsdalite and plumbogummite are produced quite readily. In the replacement of pyromorphite by either one, almost a quadrupling of the number of ions in a given volume is involved and as a result considerable ionic movement must take place. Whilst sulphides persist in the zone of oxidation there would be an abundance of sulphate in the environment and the formation of hinsdalite would be favoured. If the oxidation of the ore body was virtually complete to the existing water table and phosphate remained abundant then the formation of plumbogummite could take place.

The presence of silver in the Dundas hinsdalite is worthy of note. The Beudanite Group are chemical intermediates between the phosphates of the Plumbogummite Group on one side and the sulphates of the Alunite Group on the other. The theoretical 1:1 ratio of phosphate to sulphate is seldom achieved. If sulphate is in excess, the resulting decrease in the negative charge of the mineral is counteracted by replacement of part of the divalent metal ion (lead) by a mono-valent ion (silver). On the other hand if phosphate is in excess then the higher negative charge is counteracted by the substitution of neutral water for part of the hydroxyl content.

TABLE 1

X-Ray Powder Diffraction Data for Colorado and Dundas Hinsdalite and Plumbogummite

Hinsdalite Colorado		Hinsdalite Dundas		Plumbogummite ASTM Card 2-0683		Indices	
d(*obs.*)	I/I_1	d(*obs.*)	I/I_1	d(*obs.*)	I/I_1	hkl	d(*calc.*)
5.70	92	5.70	94	5.70	80	100	5.698
5.57	30	5.57	17	..	..	111	5.573
4.90	3	4.91	17	4.84	40	110	4.909
3.50	44	3.51	59	3.79	40	$10\bar{1}$	3.500
3.45	18	3.46	22	3.45	60	211	3.440
2.964	100	2.964	100	2.97	100	210	2.964
2.930	4	2.940	11	..	..	221	2.927
2.848	11	2.857	16	2.82	20	200	2.850
2.787	15	2.788	13	..	..	222	2.785
2.452	10	2.462	13	2.44	40	220	2.454
2.269	8	2.276	13	2.26	40	$20\bar{1}$	2.270
2.248	12	2.250	13	..	..	311	2.246
2.224	86	2.226	32	..	..	322	2.223
2.211	17	2.216	27	2.20	60	$21\bar{1}$	2.212
2.183	15	2.186	13	2.09	20	321	2.180
2.018	2	2.014	10	..	..	$2\bar{1}1$ $11\bar{2}$	2.120
2.010	10	..	..	2.01	40	310	2.009
1.978	9	1.981	5	..	..	332	1.975
1.900	36	1.901	22	1.89	50	300 $22\bar{1}$	1.900
1.857	1	1.861	4	..	..	333	1.857
1.750	16	1.753	15	1.75	50	$20\bar{2}$	1.750
1.722	8	1.724	4	1.70	20	$42\bar{2}$	1.720
1.668	4	1.672	3	1.66	40	$31\bar{1}$	1.670
1.655	11	1.657	5	..	..	421	1.653
1.642	29	1.643	6	1.63	40	432	1.640
1.614	8	1.616	4	..	..	433	1.611
1.502	4	1.504	4	1.50	40	410	1.503
1.491	4	1.493	2	..	..	$22\bar{3}$	1.492
1.480	22	1.481	4	1.48	50	420	1.482
1.465	24	1.467	8	1.45	50	442	1.464
1.426	4	..	..	1.42	40	400	1.425
1.392	3	..	..	..	..	444	1.389
1.373	4	..	..	1.37	40	$31\bar{2}$	1.372

TABLE 1—*continued*

Hinsdalite Colorado		Hinsdalite Dundas		Plumbogummite ASTM Card 2-0683		Indices	
d(*obs.*)	I/I_1	d(*obs.*)	I/I_1	d(*obs.*)	I/I_1	hkl	d(*calc.*)
1.366	8	..	..	..	..	522 441	1.367
1.351	6	..	..	..	..	532	1.350
1.321	3	..	..	1.32	20	$\bar{3}12$ $21\bar{3}$	1.323
						$41\bar{1}$	1.320
1.295	7	..	..	..	..	$54\bar{3}$	1.291
1.286	9	..	..	1.28	40	$40\bar{1}$ $32\bar{2}$	1.287
						$42\bar{1}$	1.284
1.258	8	..	..	1.26	20	544	1.254
1.200	9	..	..	1.20	40	520	1.202
						$41\bar{1}$	1.200
1.185	8	..	..	1.19	20	553	1.181
1.173	3	..	..	1.17	20	554	1.173
1.147	1	..	..	..	..	533 552	1.144
1.141	2	..	..	1.14	20	$31\bar{3}$	1.143
						$41\bar{2}$	1.142
						500	1.140
1.121	6	..	..	1.12	40	622	1.123
						643	1.119

ACKNOWLEDGMENTS

Without access to material for investigation this publication would not have been possible. The Tasmanian Museum, Hobart, The Australian Museum, Sydney, and Dr. L. J. Lawrence, Sydney, have all been most helpful in this matter.

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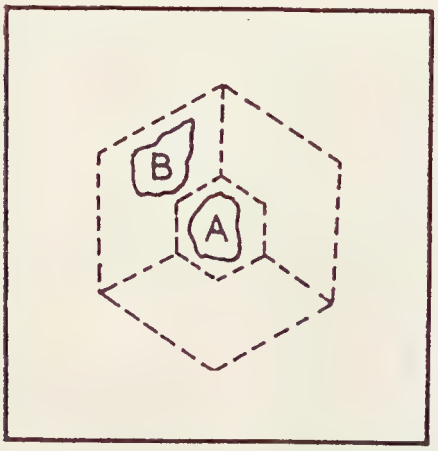

FIGURE 1 Optical anomalies in hinsdalite – core fragments "A" are uniaxial, peripheral fragments "B" are biaxial.

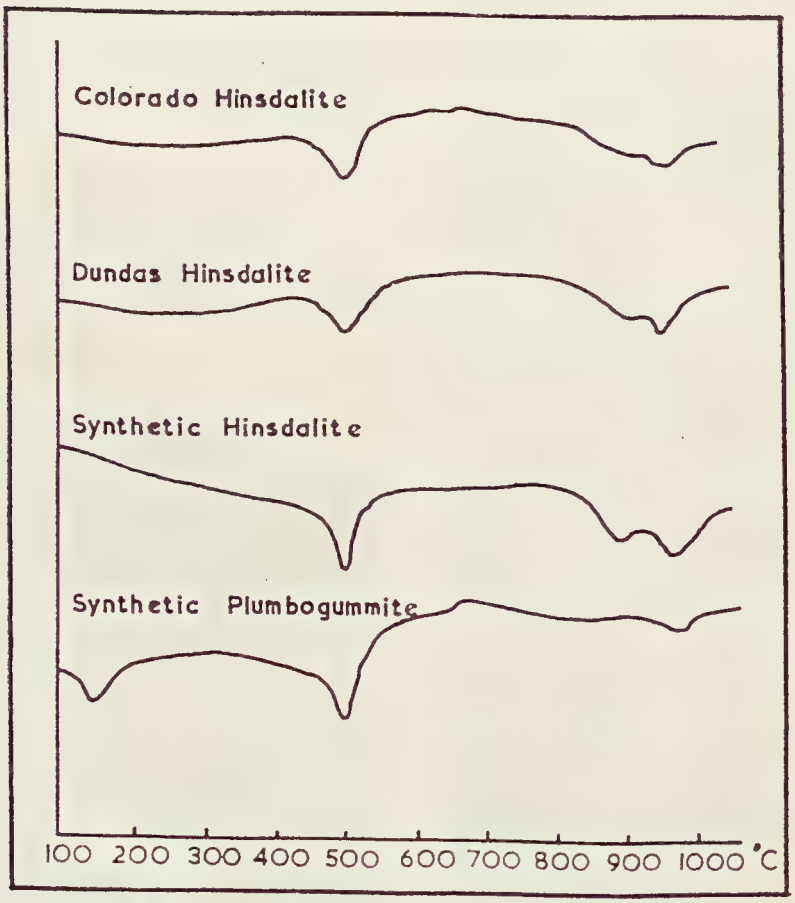

FIGURE 2 Differential thermal analysis curves for hinsdalite and plumbogummite.

PAPERS AND PROCEEDINGS

OF

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The Royal Society of Tasmania

Volume 98

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Royal Society of Tasmania

Papers and Proceedings Volume 98

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Royal Society of Tasmania

Annual Report for the Year 1963.

On behalf of the Council of the Royal Society of Tasmania I have the honour to present the Annual Report for the year 1963.

Lord Rowallan.

While Lord Rowallan was Governor of Tasmania he occupied the position of President of the Society following the precedent established by Sir Eardley Wilmot in 1843 and followed by each Governor in turn since that date. During the years Lord Rowallan was in Tasmania he took a very special interest in the affairs of the Society and when he was due to leave he was elected an Honorary Life Member. This honour was conferred on him at the March meeting when he was presented with an address similar to that given in 1862 to Sir H. E. Fox Young, then Governor of Tasmania. When replying, Lord Rowallan mentioned the interest and pleasure he had received from the Society and offered good wishes for the future.

Tasmanian Museum.

In January, 1863, the Royal Society was able to open its new museum which was built on the site occupied now by the Tasmanian Museum and Art Gallery. To commemorate this event the Trustees of the Museum arranged a series of four lectures. One was devoted more especially to the association of the Museum with the Royal Society and on that occasion the lecture was given by Professor J. Burke, O.B.E., of the University of Melbourne. At the first lecture, His Excellency the Governor, Lord Rowallan, President of the Royal Society of Tasmania, gave an address entitled, "The Museum and the Community".

General Meetings.

General meetings were well attended and addresses were given as follows:—

March: Sir Stanley Burbury, Chief Justice of Tasmania, on "*Law and Science*".

April: Professor J. Burke, Department of Fine Arts, University of Melbourne, on "*Some Aspects of the Early History of the Arts in Tasmania*".

May: Scientific Films.

June: Mr. D. F. Hobbs, Commissioner of Inland Fisheries, on "*New Concepts in Trout Fisheries Management*".

July: Professor Peter Scott, University of Tasmania, on "*Hobart's Population: a Demographic and Social Analysis*".

August: Dr. M. Cunningham, Forestry Department, on "*Today's and Tomorrow's Forests in Tasmania*".

September: Mr. G. K. Meldrum, Chief Veterinary Officer, Department of Agriculture, on "*The Threat of Exotic Diseases*".

October: Mr. J. Greenhill, University of Tasmania, on "*Some Aspects of Antarctic Research*".

November: Miss Ann Phillips, University of Tasmania, on "*Some Aspects of the Ecology of the Fairy Penguins*".

Special Lectures.

Another series of scientific lectures was arranged and the following papers were read:—

June: Mr. J. L. Davies, University of Tasmania, on "*Periglacial Geomorphology in Tasmania*".

July: Dr. B. I. H. Scott, University of Tasmania, on "*The Role of Plant Membranes in Regulating Ion Movement*".

August: Dr. G. H. Cheesman, University of Tasmania, on "*The Investigation of the Sense of Smell*".

September: Mr. K. J. Taylor, C.S.I.R.O., on "*Sirex Problems*".

These meetings, held at 5.15 p.m., once again showed that there is a place for lectures by scientists dealing in greater detail with their particular subjects, and it is evident that a similar series should be given each year.

Annual General Meeting.

This meeting was held on 5th March, 1963, when the Annual Report and Statement of Accounts for the year 1962 were presented and adopted. The retiring office-bearers were thanked for their services and the following were elected to fill the vacancies arising through retirement:—

Vice-President: Mr. D. H. Borchardt.
Members of Council: Professor A. M. Clark and J. V. Cook.

The following were re-elected:—

Honorary Secretary and Honorary Librarian: Dr. W. Bryden.
Honorary Treasurer: Mr. G. E. A. Hale.
Honorary Auditor: Mr. A. D. Hewer.

The address was given by Sir Stanley Burbury, K.B.E., Chief Justice of Tasmania, on "*Law and Science*".

Papers and Proceedings.

Volume 97 of the "Papers and Proceedings" was printed and distributed in the usual way.

Wedge Diaries.

The Diaries of John Helder Wedge, 1824-1835, were edited by the Hon. Mr. Justice Crawford, Mr. W. F. Ellis and Mr. G. H. Stancombe, and published by the Society.

Royal Society of London.

It was with particular pleasure that members learned of the election of Professor N. H. Barber, who until recently occupied the Chair of Botany in the University of Tasmania, to Fellowship of the Royal Society of London. All members of the Society join in extending hearty congratulations to Professor Barber.

Library.

Many periodicals, in addition to those obtained by subscription, were received by the Library during the year in exchange for the "Papers and Proceedings". The practice of binding a number of the more important periodicals was continued.

The total number of volumes added during the year was 550.

Membership.

Membership of the Society this year reached a total of 616.

Northern Branch.

Members of the Northern Branch of the Society have had another active year with a varied programme of lectures and a number of very informative excursions.

In September the Council of the Society held its meeting in Launceston.

Acknowledgments.

The Council wishes to record its appreciation of the work carried out by the various office-bearers and staff, to the Tasmanian Government, the University of Tasmania, the Press, the Tasmanian Museum and Art Gallery, and to all who have helped during the year.

W. BRYDEN, Hon. Secretary.

Northern Branch

Annual Report, 1963.

The Council of the Northern Branch was composed as follows during 1963:—

Chairman: Mrs. I. J. Mead.
Vice-Chairman: Mr. T. E. Burns.
Past Chairman: Dr. C. Craig.
Honorary Secretary and Treasurer: Mr. W. F. Ellis.
Members of Council: Mr. Justice G. H. Crawford, Mr. J. M. Curtis, Mr. A. W. G. Powell, Mr. J. R. Skemp, Mr. K. R. von Stieglitz.

Mrs. Mead and Mr. Ellis represented the Branch on the General Council of the Society, Mrs. Mead also attending the Standing Committee. Mr. Justice Crawford acted as the Northern Branch nominee on the Cradle Mountain-Lake St. Clair National Park Board.

Membership.

On 31st December, 1963, the Northern Branch had 254 members comprising 12 Life Members, 234 Ordinary Members and 8 Associate Members. During the year the following adjustments were made:—

New Members Elected	40
Transferred to Branch	2
Transferred from Branch	4
Resigned	10
Deceased	2
Removed	3

Activities.

Ten General Meetings and one Special Meeting were held during the year, at which the following addresses were given:—

11*th December*, 1963: "Timing as a factor in the emergence of distinctively human characteristics", by Professor A. A. Abbie, M.D., Ph.D., F.R.A.C.P.

22*nd March*, 1963: "Tasmania's secession—the history of the Bass Strait", by Professor S. W. Carey, D.Sc.

24*th May*, 1963: "The first convict period on Maria Island", by Mr. John Morris.

28*th June*, 1963: "A Physicist in the Antarctic" by Mr. John Phillips, B.Sc.

26*th July*, 1963: "Television studio technical facilities", by Mr. V. F. Kenna, S.M.I.R.E.

15*th August*, 1963: "Tasmanian eucalypts in the British Isles", by Dr. D. Martin, D.Sc.

20*th September*, 1963: "Economic and social aspects of forest management in Tasmania", by E. P. Johnston, Dip.For.

25*th October*, 1963: "The significance of the temperance movement in Australia (1830-1950)", by Dr. M. Roe.

15*th November*, 1963: "Mental health, past, present and future", by Dr. N. Gold, M.B., B.S., M.R.C.S., L.R.C.P., D.P.M.

6*th December*, 1963 (Members' Night):

"West Coast Scenes", by Mr. A. W. G. Powell, M.Sc., B.Ed., F.R.A.C.I.
"Campbell Town", by Miss N. King.
"Governor Franklin's trip to the West Coast", by Mr. K. R. von Stieglitz, O.B.E.
"An outline of insect structure", by Mr. J. Glennie.
"What a piece of work is man", by Mr. G. H. Stancombe.
"Our talented society", by Mr. R. S. Smith, F.R.I.B.A., F.R.A.I.A.

The Special Meeting was held in 3rd April, 1963, when Professor Joseph Burke, O.B.E., M.A., spoke on "Some aspects of the fine arts in early Tasmania".

The attendance at each meeting averaged 87 persons.

Excursions.

Six day excursions were arranged:—

17*th February*, 1963: "Clairville" and "Glendessary", Western Junction.
24*th March*, 1963: Geology of the Launceston District (Part I).
21*st April*, 1963: Freshwater Point.
9*th August*, 1963: TNT 9 Television Studios.
17*th August*, 1963: Geology of the Launceston District (Part II).
21*st September*, 1963: Forestry plantations in North-Eastern Tasmania.

Two week-end excursions were also conducted. On the first, held on 18-19 May, 1963, members visited Queenstown and Strahan on the West Coast and H.E.C. and other places of interest on the Central Plateau. On 23-24 November, 1963, an excursion to Flinders Island was held.

Council Activities.

The Northern Branch Council met seven times during the year, and one meeting of the General Council of the Society was held in Launceston.

Acknowledgments.

The Branch Council acknowledges, with appreciation, the facilities provided during the year at the Queen Victoria Museum by the Launceston City Council.

I. J. MEAD, Chairman.
W. F. ELLIS, Honorary Secretary.

PAPERS AND PROCEEDINGS OF THE ROYAL SOCIETY OF TASMANIA, VOLUME 98

THE GEOLOGY OF THE MT. BISCHOFF DISTRICT

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(With two plates and seven text figures)

ABSTRACT

The basement rocks of the area are the Upper Precambrian (?) Bischoff quartzites and slates, which comprise a 2000 ft. succession of quartzites and sheared mudstones with a bed of dolomite in the upper part of the succession. These sediments have undergone considerable deformation during the pre-Cambrian and/or early Cambrian but show apparent conformity with the overlying mudstones, sandstones, greywackes, volcanic breccias and spilitic lavas of Cambrian (?) age. Late in the Cambrian, ultrabasic and basic dykes were intruded.

The Precambrian (?) and Cambrian (?) rocks were folded into a westerly plunging anticlinorium, with smaller subparallel folds on the limbs. These are distorted by small ENE folds and NNW faults. A granitic body underlies the area and radiating quartz porphyry dykes probably associated with a local, narrow cupola intrude the core of the anticlinorium at Mt. Bischoff. Greisenization of the porphyries is extreme, with the formation of topaz, tourmaline, muscovite, and cassiterite pseudomorphing primary feldspar. Mineralisation associated with igneous activity has resulted in selective replacement of the dolomite bed at Mt. Bischoff by iron sulphides, talc, quartz, carbonate and cassiterite, and the filling of tension fissures throughout the area. A zonation of mineral deposition around Mt. Bischoff is suggested by a nucleus of tin mineralisation with an outer rim of lead-zinc mineralisation. By analogy with other areas in Tasmania the folding, granitic intrusion and associated mineralisation are considered to have occurred during the Tabberabberan Orogeny (Middle Devonian).

Tertiary terrestrial sediments and basalts unconformably overlie older rocks and form a widespread plateau.

PHYSIOGRAPHY

The dominant topographic feature of the Waratah area is an extensive dissected plateau lying at an altitude of 2000 to 2100 feet. This gently undulating plateau is underlain by flat-lying, non-marine, Tertiary sediments and basalt to a depth not exceeding 150 feet, indicating an original Tertiary land surface at an elevation of about 1900 to 2000 feet. The plateau extends down to an altitude of about 1800 feet to the west of the Mt. Cleveland Range and rises to 2200 feet in the north-eastern and central section of the Mackintosh area. Inland from there, a series of accordant summits lie between 3000 and 3500 feet, this level corresponding in elevation to the Lower Plateau Surface of Davies (1959).

Rising above this plateau area are several residual mountains including Mt. Bischoff (2598 feet), Mt. Cleveland (3200 feet), Mt. Meredith (2500 feet), Mt. Ramsay (3890 feet), St. Valentine Peak (3640 feet) and Mt. Pearse (3000 feet). These mountains owe their prominence and shape to the rock types of which they are composed; for example the shape of Mt. Bischoff is conditioned by the distribution of the porphyry dykes, Mt. Cleveland has a resistant backbone of Cambrian chert, and the arcuate form of Mt. Pearse reflects a plunging syncline in Owen Conglomerate.

Two main drainage systems have developed since the uplift of the land surface that followed pre-basalt peneplanation; these are the Pieman and Arthur River systems. The Pieman follows a westerly course some 30 miles to the south of Waratah while the Arthur rises in the Waratah District, flows northerly for 35 miles and then westerly, emerging at the coast about 50 miles north of the Pieman River. The Magnet Range forms the watershed between the tributaries of these two rivers, the Whyte River flowing westerly to the Pieman while Magnet Creek and its tributaries join the Arthur River to the east (Fig. 1). The streams generally meander slowly to the margins of the plateau, from which they fall in a series of rapids and small waterfalls to the valley floors some 800 to 900 feet below. Some structural control is suggested for the course of the Waratah River, the river trending just east of north and then swinging sharply to just north of west (Fig. 2); these directions may represent Tertiary structural lines.

In general, the Waratah area can be described topographically as comprising an extensive, deeply dissected plateau area, with sporadic monadnocks rising some 1000 feet above plateau level.

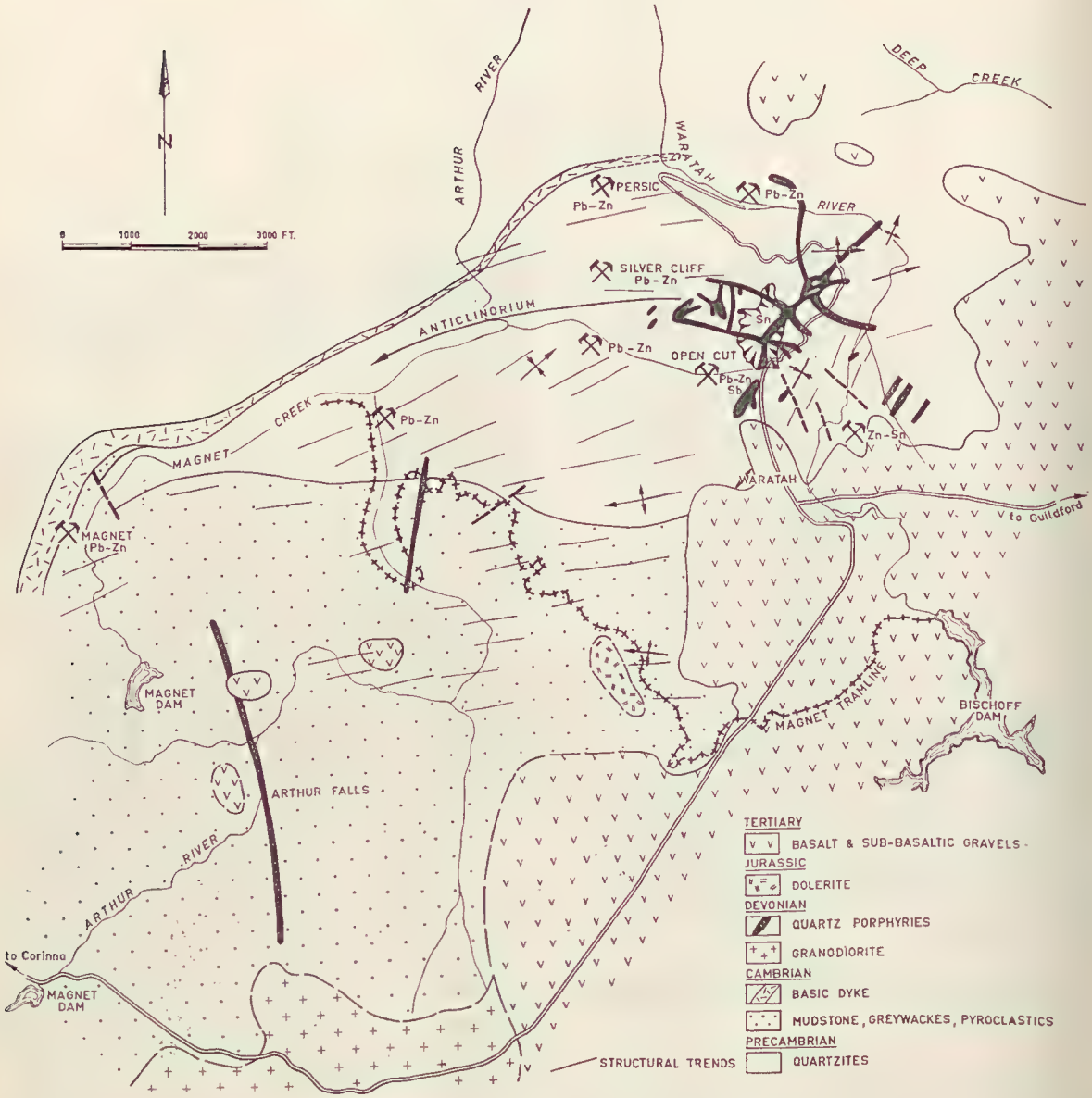

FIG. 1.—Sketch map of the Mt. Bischoff district.

FIG. 2.—Geological map of the Mt. Bischoff district.

STRATIGRAPHY

The basal sedimentary rocks in the area are Upper Precambrian (?) quartzites, sheared shales and dolomite which were previously called the Mt. Bischoff Series by Reid (1923) and are here called the Bischoff quartzites and slates. Overlying these rocks is a thick sequence of shales, mudstones, greywackes, subgreywackes, cherts and altered lavas which were previously called the Dundas Series and are here called Cambrian (?) sediments as their correlation is somewhat obscure. These sediments show apparent structural conformity with the Bischoff quartzites and shales. Unconformably overlying these sediments are conglomerates, sandstones and lignites of Tertiary age, which are generally covered by basalt (Fig. 2).

The succession is summarised below:—

Quaternary—
River gravels and alluvium.

Tertiary—
Gravels, conglomerates, siltstones and lignite: 50-100 ft.
—Unconformity—

Cambrian (?)—
Cambrian (?) argillites, greywackes, breccias, cherts and altered laves: +10,000 ft.
—Disconformity—

Precambrian (?)—
Bischoff quartzites, slates and dolomite: +2,000 ft.

PRECAMBRIAN

Bischoff quartzites and slates

These crop out in a relatively narrow, E-W trending inlier that extends from the head of Deep Creek (east of Mt. Bischoff) to the Magnet Mine. They consists of alternating quartzites and sheared shales and siltstones, with a bed of dolomite and associated dolomitic shales. The sequence shows strong lithological similarities to the Rocky Cape Group on the North West Coast of Tasmania (Spry, 1957) and the Oonah Quartzite and Slate in the Zeehan area (Blissett, 1962), both of which are considered as Upper Precambrian. A correlation of these rocks with similar sediments of Upper Precambrian age was also suggested by Carey (1953) and Knight (1953), the sequence previously being regarded as Ordovician.

The succession in the vicinity of Mt. Bischoff is:—

Hangingwall Shales and Quartzites: +1000 ft.
Dolomite, including dolomitic shales: 0-200 ft.
Footwall shales: 0-30 ft.
Footwall quartzites, shales and siltstones: +1000 ft.

This succession differs from that given by Knight (1953), mainly in the addition of the Hangingwall sediments.

The Footwall quartzites and shales are dominantly thinly bedded although massive sequences of 15 feet in a single rock type have been observed. The quartzites contain a high proportion of quartz which has been quite strongly sheared, and thus gives no indication of original angularity and sphericity of grains. The quartz grains exhibit sub-parallel grain and optical elongation and marked undulose extinction, and are in places crushed. The grains vary from 0.1 mm. to 0.5 mm. in diameter. Muscovite occurs in most sections and is quite abundant in several, generally occurring as elongate flakes, 0.1 mm. to 0.4 mm. in length, which are aligned parallel to the elongate quartz grains. Quartz and muscovite comprise the only large grains present, these being set in a matrix of fine sericite and chlorite with sporadic occurrences of interstitial microquartz cement. Minor accessory minerals include well rounded grains of rutile, zircon and tourmaline with graphitic bands and flecks of limonite. Hypogene pyrite is common throughout these sediments.

The sheared shales or mudstones are well laminated and extremely fine grained (0.01 to 0.02 mm. diameter), and consist of quartz, muscovite, sericite and microquartz as in the quartzites. The laminations appear to be produced by variations in the proportion of muscovite which is also found abundantly on the bedding planes. An anlysis of a shale from the mine area at Mt. Bischoff (Table 1) indicates that the sheared shales at Mt. Bischoff are apparently more mature than the average shale, having a higher K_2O to Na_2O ratio, and are more siliceous. However, they do not contain as much silica as the siliceous shale and are probably an intermediate type.

Some thirty thin sections of quartzite and sheared shales from throughout the exposed sequence were examined, and it was found that the sediments in the upper portion of the sequence contained up to 70% quartz grains while the sediments exposed in the Waratah River contained only 50 to 60% quartz. It is also apparent that the sediments become distinctly 'cleaner' towards the upper beds, microquartz cement dominating the normal sericitic matrix. Statistical examination of fairly continuous sections of these sediments in the Mt. Bischoff area and in the Waratah River east of Mt. Bischoff (see Fig. 4) revealed that the Mt. Bischoff section comprised 58% quartzites and 42% shales while the Waratah River section comprised 72.5% quartzites and 27.5% shales. Thus there appears to be an increase in shales towards the top of the sequence, accompanied by an increase in the silica content of the sediments.

Table 1

Analysis of shale from Mt. Bischoff compared with other shales.

	I	II	III
SiO_2	77.18	58.10	84.14
TiO_2	0.59	0.65	0.22
Al_2O_3	11.96	15.40	5.79
Fe_2O_3	1.70	4.02	1.21
FeO	0.38	2.45	—
MnO	trace	—	—
MgO	0.99	2.44	0.41
CaO	0.20	3.11	0.31
Na_2O	0.12	1.30	0.99
K_2O	3.27	3.24	0.50
H_2O—	2.21	5.00	5.56
H_2O+	2.20		
FeS_2	0.13	—	—
CO_2	0.63	2.63	—
	99.56	98.34	100.03

I.—From Mt. Bischoff. Analyst: Department of Mines, Assay Laboratories, Tasmania. 1962.
II.—Average shale (Pettijohn, 1956).
III.—Siliceous shale (Pettijohn, 1956).

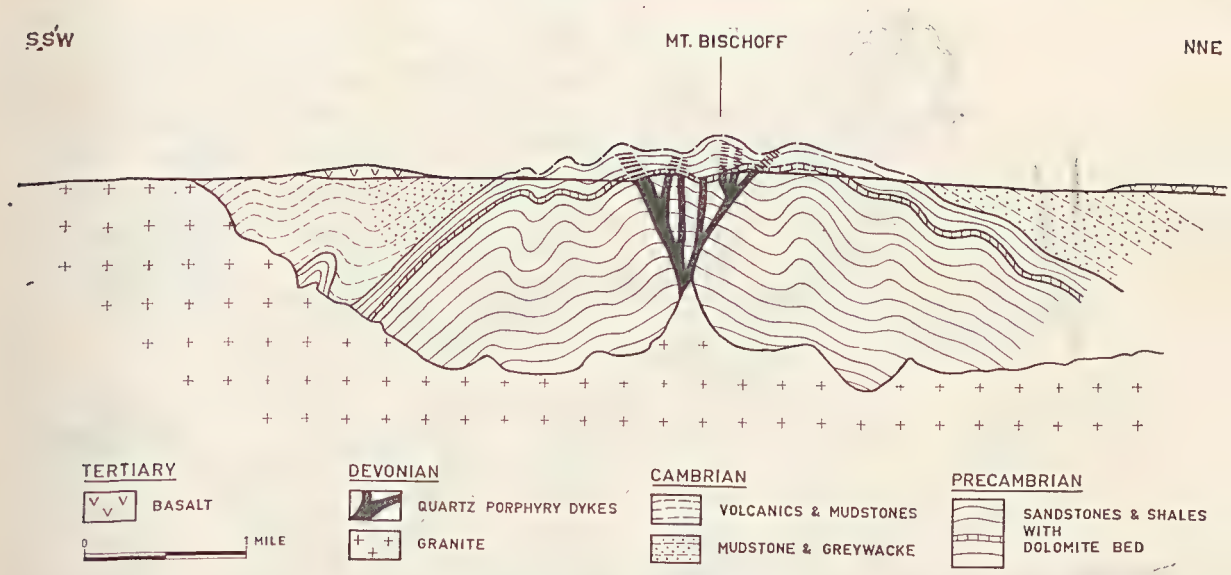

FIG. 3.—Generalised section across Mt. Bischoff.

The Footwall shales are dark grey in colour, lenticular, and represent a local transition to dolomite.

The dolomite is creamy or pale grey when fresh and weathers to pale brown or fawn. Thin sections of the dolomite (30649, 30649 (a)[1], and 36.R.2 of the Mines Department indicate a fine-grained rock consisting almost exclusively of crystalline dolomite with minor interstitial quartz grains. Irregular patches of coarsely crystalline carbonate were developed during recrystallization related to mineralisation. The dolomite also exhibits a fine macroscopic banding which may represent bedding.

Analyses of the dolomite (Table 2) indicate that it is composed of almost pure dolomite mineral, Knight (1953) also indicating the presence of less than 1% MnO in the dolomite. The thin banding (bedding ?) and fine grained texture of the dolomite, and its concordant relations to contiguous rocks, indicate a sedimentary origin (see also Knight, 1953). Thin bedded dolomitic shales occur within the dolomite at the Greisen Face and at the portal of the Main Tunnel.

Table 2

Analyses of Dolomite from Mt. Bischoff

	I	II
Weight %—		
$CaCO_3$	54.6	53.9
$MgCO_3$	43.5	44.1
Mole %—		
$CaCO_3$	50.4	49.7
$MgCO_3$	47.8	48.3

I.—Hangingwall of Greisen Lode, Mt. Bischoff. Analyst: Department of Mines Assay Laboratories, 1959.
II.—50 feet from portal, Main Tunnel, Mt. Bischoff. Analyst: Department of Mines Assay Laboratories, 1959.

[1] Specimen numbers refer to a collection in the Geology Department, University of Tasmania unless stated otherwise.

The dolomite reaches a maximum thickness of 250 ft. at Mt. Bischoff but is only about 100 ft. thick two miles to the north of the mountain. It has not been found elsewhere, either because it is lenticular or has poor outcrops.

The sediments above the dolomite, the Hangingwall quartzites and shales, are similar to those below, and are dominantly sheared shales.

Pre-consolidation structures occur within both the Footwall and Hangingwall sediments. Somewhat deformed flow casts are exposed on a bedding surface on the North Valley Road, Mt. Bischoff and deformed examples occur in the Waratah River, ½ mile below the mill (Plate I, Fig. 1). As the structure is difficult to determine in these areas no attempt has been made to determine current directions.

Small-scale cross-bedding is visible in some of the coarse siltstones and quartzites but no graded bedding has been observed.

The most widespread feature is the crumpling and brecciation of the sediments; contortion may be confied to a layer a few inches thick between undisturbed material, or may involve several tens of feet of sediments. Plate I, Fig. 2, illustrates a type in which the sand matrix has been liquefied and has incorporated fragments of adjacent mud layers, which retained a shearing strength during the deformation.

The sandstones (Hanging Wall ?) above the Greisen Face (Mt. Bischoff) are almost entirely very contorted and/or brecciated, so that the orientation of the rock is obscure. The deformation has a pre-consolidation appearance and involves fine-grained sandstones with little or no shale; in this case several tens of feet of sandy material appear to have been disturbed.

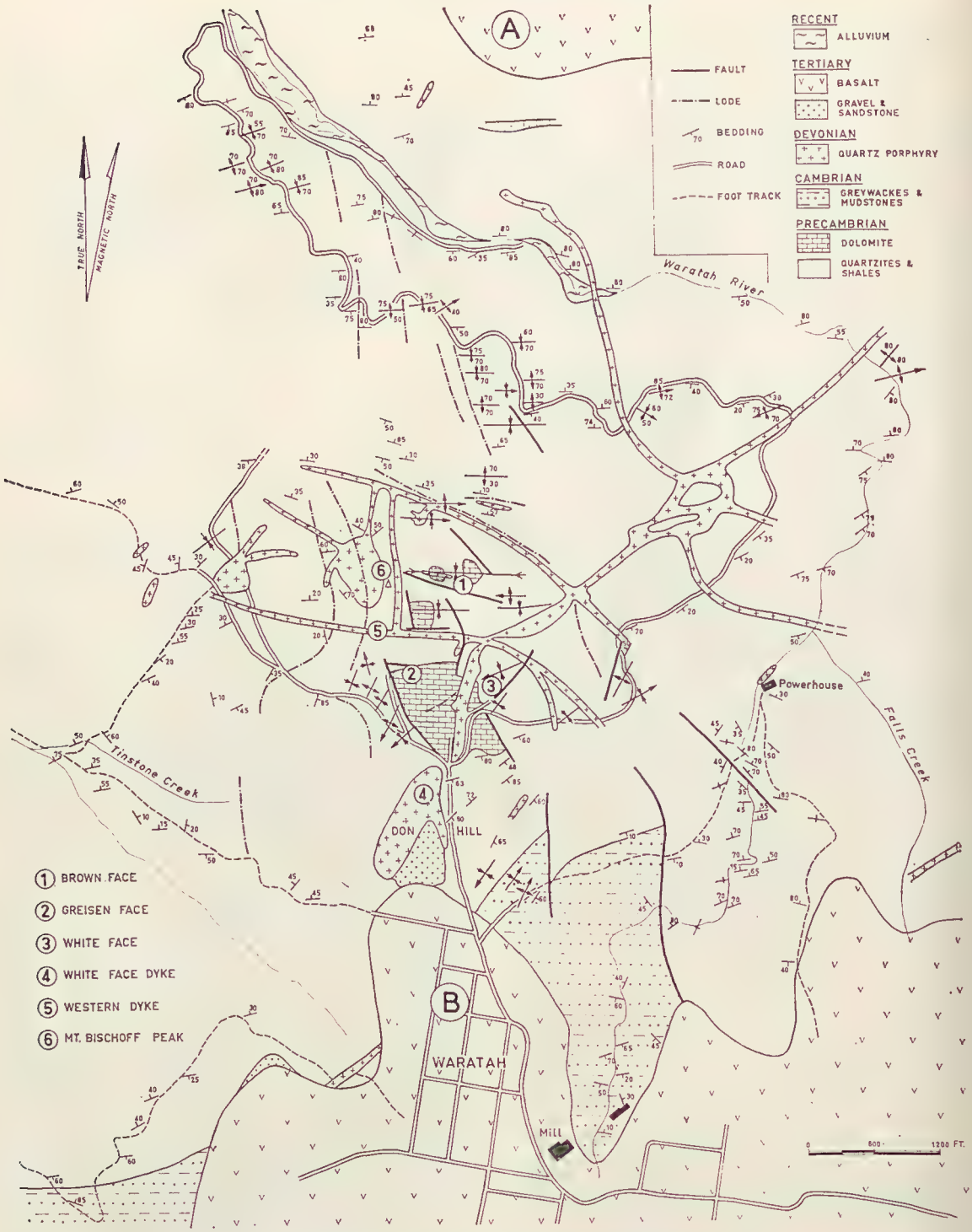

FIG. 4.—Geological map of the Mt. Bischoff mine area. For Section A-B see Fig. 5. Base map by courtesy Lands and Surveys Dept.

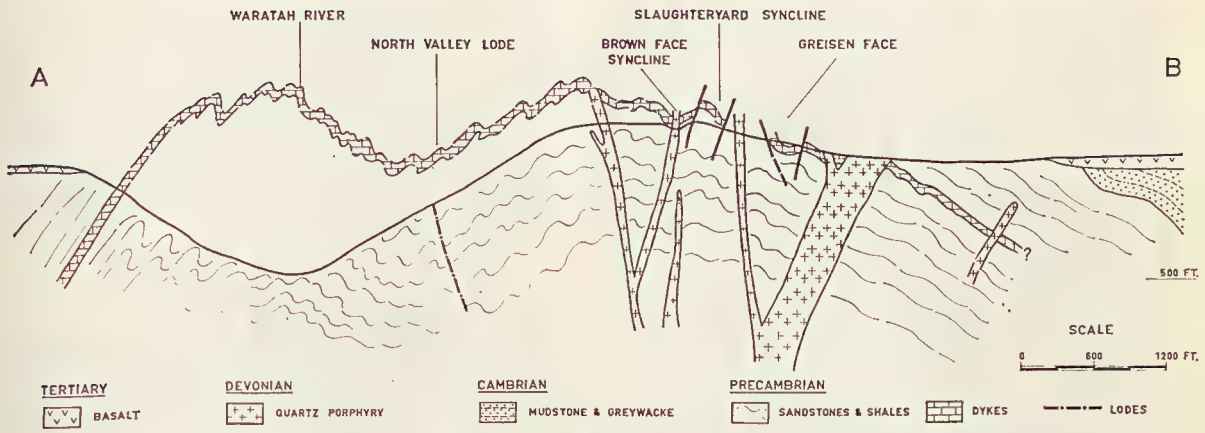

FIG. 5.—Section A B across Mt. Bischoff—see Fig. 4.

Another type exhibits bands of crumpled and brecciated sandstone within a dark shale matrix; the sandstone bands vary from a few mm. to 1½ cm. thick and the shale matrix is generally the dominant lithology. The mechanism in this type is probably the "quickening" of clays containing plastic sandy layers.

CAMBRIAN

Cambrian (?) sediments

These sediments occupy the major portion of the Waratah area and are mainly chocolate-coloured, finely laminated to massive mudstones with minor yellow-brown to grey mudstones, greywackes, subgreywackes, cherts, chert breccias, sandstones and altered lavas. The boundary between these beds and the Bischoff quartzites and slates is not exposed although to the south of Don Hill and on the Magnet Tram they crop out within several feet of each other. At these localities they appear conformable, although the change in lithology from siliceous shale to greywacke is abrupt and the Bischoff quartzites and slates are much more severely deformed than the overlying sediments.

Chocolate coloured mudstones are the dominant sediments in the area. These are extremely fine grained rocks in which even in thin section the constituent minerals are unrecognizable. Haematite and limonite are abundant, producing the red colouration, and thin carbonate veins are also present. In the Waratah River section these mudstones are rare and the finer sediments are grey, black and yellow-brown laminated mudstones which consist of extremely small, angular fragments of quartz, plagioclase, sericite, and calcite. The laminations are apparently caused by thin bands of limonite and graphitic material. The predominant rock types exposed in the Waratah River are subgreywackes, which also occur sparsely throughout the remainder of the area. The rocks are poorly sorted with an open framework and consist dominantly of angular quartz grains, several of which are elongate and exhibit undulose extinction. Other clastic grains include rounded albite, hornblende, augite, chlorite, magnetite and rare rock fragments. They range in grain size from 0.2 to 0.8 mm. diameter and generally the grains are not quite in contact. The matrix consists of chlorite, iron ores and small fragments of other minerals.

Specimen 30659, from the old Magnet tram-line, consists mainly of isolated grains, up to 0.2 mm. diameter, of angular to sub-angular quartz and rounded feldspar, chlorite and magnetite (in order of abundance). The feldspars are interesting in that while a few grains of fairly fresh albite are present, the majority appear to be similar to microcline. Most of these show a very fine, spindle like normal albite twinning and some show pericline cross-twinning; they are optically negative and 2V measurements range from 79° to 87°. Several contain blebs and irregular patches of clear quartz and some crystals appear to be almost entirely replaced by quartz. The significance of these feldspars will be discussed in the section on igneous activity. Somewhat deformed amygdule-like bodies filled with a fine quartz aggregate are also present, with a few flakes of muscovite and small fragments of fine grained basaltic lava.

Other rocks are similar (30655, 30657, 30658, 30660) but vary in quartz (up to 40%) and iron oxide content. Specimen 30657b is unusual in that the matrix has several percent of small (0.05 mm. diameter) hornblende crystals, apparently as a detrital component.

Coarser grained sediments (mainly fine to coarse breccias) are common throughout the area. Many of these rocks contain a high percentage of albite laths and angular volcanic rock fragments with or without clastic muscovite. Fragments of shale are also common, occurring with minor quartz, biotite, carbonate and limonite in a fine matrix of chlorite, albite and a little quartz. Some of the breccias have a much lower volcanic component,

e.g., the breccia outcropping in the Waratah River, ¼ mile below the Bischoff mill, which has indistinct bedding and is composed dominantly of angular rock fragments of the Bischoff quartzites and slates and Cambrian (?) sediments; several lava fragments are also present. The fragments are several inches in diameter (to a maximum of 9 inches) and angular to subangular.

Some of these rocks may be volcanic but the presence of quartz and sedimentary rock fragments in quantity suggests they are not tuffs and may be the result of weathering of volcanic and Pre-Cambrian rocks.

Nye (1923) classified these greywackes and breccias as micaceous or feldspathic "breccias" but the number of sediments in which mica was an important constituent proved to be very small while almost all of them contained feldspar.

Lavas and pyroclastics are rare in the Mt. Bischoff area but become more common towards the Magnet Mine where they are associated with a massive bed of banded chert and chert breccia. The volcanic rocks are described in detail in a later section.

An interesting member of the Cambrian (?) sediments in the Arthur River to the north of Waratah is a thin bed of limestone interbedded with yellow-brown laminated mudstones. The limestone is dark grey in colour, fine grained and contains small bands of coarsely crystalline calcite. The thickness of the bed is unknown due to limited exposure.

The Cambrian (?) sediments are apparently unfossiliferous throughout the area although Chapman (1929) records annelid remains (described as arthropod tracks—*Tasmanadia twelvetreesi*—by Glaessner, 1957) in slates on the Arthur River a few miles north-west of Waratah.

On the grounds of lithologic similarity, the Cambrian (?) sediments in the Waratah district have been carrelated with the Dundas Group of Middle to Upper Cambrian age (e.g., Knight, 1953) and also beds lower in the Cambrian (Banks, 1962).

At the present time no direct correlation with other sequences is possible and attention can only be drawn to the similarities of the Waratah rocks to those of the Huskisson River and Dundas areas.

TERTIARY

The beds belonging to the Tertiary System consist of conglomerates, gravels, siltstones, sandy clays and lignites, forming a sequence generally some 50 feet in thickness and reaching 100 feet in places.

The basal members consist of conglomerates and gravels containing boulders up to 12 inches in diameter. Small quantities of cassiterite and gold have been found in these basal beds. Above these are fine grained, poorly sorted siltstones with water worn pebbles and unevenly distributed boulders that distort the bedding. The boulders have been locally derived, consisting of quartz, quartzite, shale, greywacke, breccia, quartz porphyry and granodiorite. Boulders of Permian mudstones have also been found (Nye, 1923). Small outcrops of lignite and ligneous clays occur in the vicinity of Waratah and contain numerous leaf impressions which have been described by Johnston (1888) as belonging to the genera *Eucalyptus, Quercus, Laurus, Cycadites* and *Ulmus*. This and the lithology indicate a terrestrial origin for these sediments and they are thought to have been deposited in streams and small lakes. At Don Hill (Fig. 4) Tertiary sands may be seen deposited against low bedrock cliffs. Differential compaction of the younger sediments has produced folds and high dip angles near these cliffs (Plate I, Fig. 3).

IGNEOUS ACTIVITY

Five major periods of igneous activity are represented within the Waratah area:

(a) Volcanic emission during deposition of the Cambrian (?) sediments, with the production of dominantly basaltic lavas.
(b) Intrusion of ultrabasic and basic igneous rocks, probably soon after cessation of deposition of the Cambrian (?).
(c) Intrusion of acidic rocks including granodiorites and quartz-feldspar porphyries into the Bischoff Series and Cambrian (?) sediments during the Devonian.
(d) Intrusion of dolerite during the Jurassic.
(e) Extrusion of basalt over a vast area during the Tertiary.

(a) CAMBRIAN VOLCANIC ACTIVITY

Lavas are generally rare in the Cambrian (?) sediments but become more prolific towards the Magnet Mine. Individual flows appear to have covered considerable areas, an example in the Arthur River (near the confluence with the Waratah River) outcropping at fairly close intervals over about ½ mile; the maximum exposed thickness is 100 feet. The lavas examined are mainly spilitic (e.g. 636, 642, 30658a, 30662a and 35G5, 35G9 of the Mines Department). Many are porphyritic, with phenocrysts of albite, augite and chlorite in a felted ground mass of albite laths, chlorite, calcite, epidote, magnetite and ilmenite. Some have intersertal texture and consist of an interlocking aggregate of albite, augite and chlorite with interstitial chlorite, calcite, &c. The albite phenocrysts are almost invariably clouded by sericite and in some appear to be completely altered to a fairly coarse interwoven aggregate of sericite plates and sheaves. They reach a maximum size of about 2 x 0.5 mm. As in the spilites elsewhere in Tasmania the albite displays low-temperature optics and varies in composition between Ab_{90} and Ab_{95}. Augite occurs in only a few of the rocks, and is altered to varying degrees to chlorite, or a very fine grained dusty aggregate of chlorite and possibly sericite (e.g. 30662a). The augite is similar to that described by Scott (1954) in the Lynch Creek basalts at Queenstown; this proved to be a diopsidic variety. Chlorite may be primary but in some rocks it is clearly pseudomorphing earlier minerals, probably augite (e.g. 642) and in some cases possibly olivine (e.g. 30662b). Most of the chlorite shows anomalous "Berlin Blue" interference colours and is very pale green in colour and non-pleochroic. Refractive index measurements gave β=1.615 and 1.633.

The ground mass is very variable; it may have a typical basaltic form dominated by thin albite laths or it may be granular. Chlorite occurs interstitially to the feldspar laths, along with calcite, epidote, magnetite and ilmenite.

Some of the rocks are amygdaloidal, the amygdules being of ovoid shape and usually filled with combinations of chlorite, calcite and quartz. In slide No. 642, an amygdule nearly 1 cm. in diameter is filled with quartz, calcite and iron oxide, and rimmed by epidote crystals arranged radially. Calcite and chlorite veinlets are common and prehnite occurs rarely.

A specimen from a lava on the Magnet tram (30662b) consists entirely of euhedral chlorite pseudomorphs up to 2 x 2 mm., in a matrix of chlorite and quartz spherulites up to 0.2 mm. diameter. The chlorite appears to be pseudomorphing pyroxene and/or olivine crystals. Amygdule-like bodies in the ground mass are composed of aggregates of fine quartz spherulites (Plate II, Figs. 1 and 2). One of the "phenocrysts" which has a rim of quartz spherulites consists of chlorite and a fine grained quartz aggregate which appears to be partially replaced by a single skeletal quartz crystal.

Chlorite-quartz spherulite rocks occur in the Magnet Dyke and quartz spherulites line the rims of amygdules consisting of chlorite with cores of calcite in a basalt (636) from the West Magnet Mine. Rather similar spherulitic quartz rocks at Zeehan are assumed by Scott (1954) to be the result of silicification of basalt but the quartz-chlorite development appears to be related to a late stage of lava solidification rather than the regional metasomatism suggested by Scott (1954).

In all specimens collected in the field, albite is the only feldspar present, an observation similar to that made by Scott. However, slide No. 636 from the West Magnet Mine, has a coarse doleritic texture with almost unaltered labradorite (An 58) laths up to 2 mm. long, interstitial areas being occupied by pale green chlorite, calcite and magnetite (?). As already described, the rock is prominently amygdaloidal with chlorite, calcite and quartz spherulites. It appears to be a basalt, or a shallow intrusive, has many textural and mineralogical features in common with the spilites, and is unlike any Tertiary basalt. If it is Cambrian it gives an indication of a parental, more calcic feldspar.

Keratophyric lavas occur about 4½ miles from Waratah on the Corinna Road (639, 640). They are porphyritic, with phenocrysts of albite laths up to 1 x 2 mm. and rare, somewhate smaller, quartz crystals. The ground mass is feldspathic and varies from basaltic to almost variolitic in texture. Rare phenocrysts of augite up to 0.4 x 0.1 mm. occur in specimen 640, along with pale green chlorite in lath pseudomorphs. Rather rounded grains of magnetite (?) up to 0.2 mm. diameter are scattered throughout. The quartz phenocrysts are rounded, euhedral, or shard-like in form, and commonly embayed in identical fashion to crystals in the keratophyres of the Mt. Read Volcanics.

Volcanic rocks with fragmental texture are not common, though some of those described as sandstones and breccias may in fact be pyroclastic. An interesting rock occurs near the head of the Arthur River (646). It consists largely of feldspar crystals, quartz spherulites rock, and basaltic fragments in a variable matrix of chlorite, iron oxides, and calcite. Part of the matrix consists of irregular veins and concretionary forms of a pale reddish-brown, isotropic mineral that is probably hydrogrossular. Scott (1951a, 1954) has described a similar mineral in the King Island spilites, in which it appears to be due to hydrothermal alteration. This rock is of uncertain origin but may be the fine-grained equivalent of an autoclastic breccia (Wright and Bowes, 1963), formed by gas explosions within lava during solidification.

The dominance of K-feldspar in the greywackes interbedded with spilites is surprising in view of the lack of any feldspar other than albite in the spilites or the keratophyres. The reason is not known but it is suggested that the microcline in the sediments is derived from potassic rhyolite or quartz keratophyre flows and necks that have been largely disintegrated by explosive activity during eruption.

(b) CAMBRIAN INTRUSIVES

Basics and Ultrabasics

Peridotites, pyroxenites and serpentinites occur extensively in a wide belt to the southwest of the Waratah District and small masses of these rocks are also present in the Waratah District. Numerous boulders of weathered ultrabasic rocks occur north and south of the Arthur River Dam on the Waratah-Corinna Road, and two small masses occur at Mt. Bischoff. These rocks are similar to other ultrabasic masses in Tasmania, e.g., at Adamsfield, Anderson Creek and Argent Tunnel, and probably belong to the same tectonic phase. With the spilites and albite gabbros they form a typical ophiolite association.

A number of gabbroic bodies intrude the Cambrian sediments west of the Magnet Mine. A typical example crops out ¼ mile east of the Whyte River bridge on the Corinna Road. It is composed almost entirely of plagioclase, hornblende and chlorite (in order of abundance) in an even grained granitic texture, the average diameter being 0.5 mm. The feldspar is loaded with inclusions (?) of yellowish-brown chlorite and sericite (?) and many of the laths possess a thin clear rim in optical continuity with the cloudy core. The plagioclase is albite or albite-oligoclase. The hornblende is somewhat fibrous and the crystals tend to be ragged. It appears to replace both augite (?) and yellowish chlorite. Its optical properties are $\alpha = 1.643$, $\delta = 1.660$, $2V = 71+$ve.

Nye (1923) refers to similar rocks west of the Whyte River some of which contain augite. Specimen 586 shows pyroxene (diopside ?) in all stages of alteration to hornblende and pale green chlorite.

Magnet Dyke

A long, narrow strip of igneous rock occurs on the contact of the Bischoff and Cambrian (?) sediments from west of the Magnet Mine to the

Persic Mine, a total distance of some 5 miles. This mass of igneous rock has occasioned some controversy, Twelvetrees (1900) and Nye (1923) considering it to be a complex dyke, and Scott (1954) suggesting on petrological evidence that it represents a strip of volcanic rocks.

The "Dyke" is generally some 200 to 300 feet in width, reaching its maximum thickness at the Magnet Mine where it is some 1000 feet wide. At the mine it has a west dip and is more or less conformable. It consists over most of its length of a single, rather variable rock type which has been previously named a diabase porphyrite. At the Magnet Mine, however, the section is more complex, Twelvetrees (1900) describing the "Dyke" from east to west as websterite porphyrite, diabase prophyrite, and orbicular or spheroidal websterite (Fig. 6).

The diabase porphyrite, which extends for the whole length of the "Dyke", is extremely variable, with albite, pyroxene, chlorite, siderite, quartz, hornblende, pyrite and ilmenite occurring in varying proportions. Commonly the rock is porphyritic with phenocrysts of altered albite, and also chlorite completely or partially pseudomorphing pyroxene. Albite porphyrite is probably a more apt term than diabase porphyrite. The albite, which occurs as multiply twinned and untwinned crystals, has been extensively sericitized. The ground mass is generally very fine and consists dominantly of albite laths and chlorite with irregular masses of quartz and carbonate, the latter also commonly occurring as veins throughout the rock. Quartz occurs rarely as large anhedral crystals associated with chlorite. Small crystals of ilmenite, sphene, columnar epidote and cubes of pyrite also occur throughout the ground mass. Circular masses of carbonate, chlorite and quartz spherulites are also common in some sections, and are similar to amygdule fillings of the Cambrian (?) basalts. The circular bodies also show similar zonation to those in the basalts, with a carbonate nucleus lined by sheaves of chlorite, and quartz spherulites forming an outer margin.

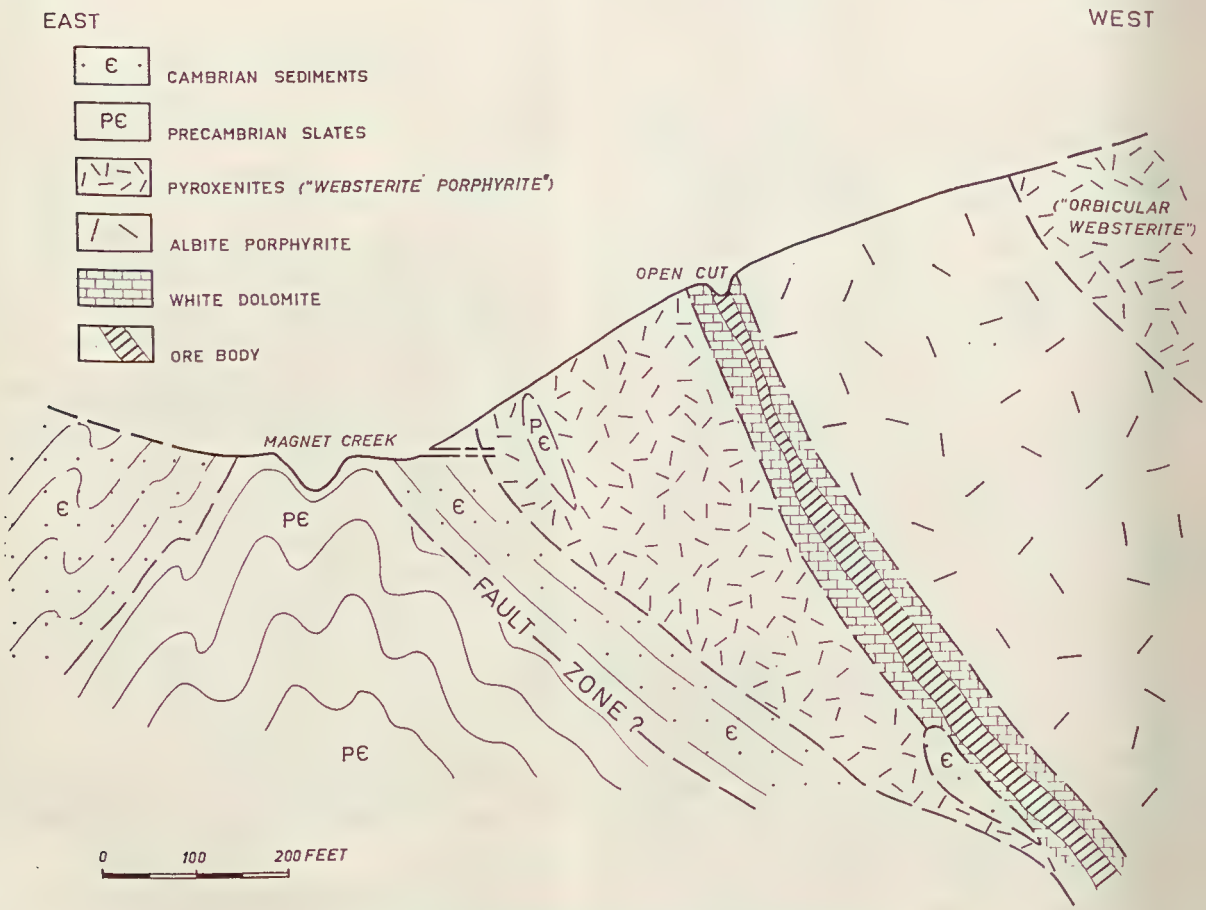

FIG. 6.—Section across the Magnet Dyke at the Magnet Mine (after Nye, 1923).

Although the albite porphyrite is dominantly porphyritic, some sections exhibit a doleritic texture. Specimen 35 N 14 (Mines Department), from the Waratah-Pieman Track, consists of interlocking laths of albite and augite with a very minor proportion of ground mass, and appears to be an altered dolerite. Specimen 712 has a similar texture and composition but also contains some hornblende and actinolite. Several of the albite crystals show myrmekitic texture.

In places the albite porphyrite consists entirely of quartz and chlorite, e.g., 708 and 35 F 11 (Mines Department). This rock consists of large spherulitic masses of quartz with interstitial sheaves of chlorite, and has been called a silicified variolite (Rosenbusch in Nye, 1923). Analyses of these "variolites" are given in Nye (1923) and quoted by Scott (1954) as intermediate phases of the silicification of spilite, the end product being a spherulitic quartz rock (99.1% SiO_2). It is suggested here that the siliceous rock is a primary, or deuteric, feature confined to lenses and channels in the spilitic body.

The pyroxenite on the east of the "Dyke" at the Magnet Mine is reported to occur as a lenticular body with a maximum width of 360 feet and thinning out to the north and south. The rock is extremely weathered, but resembles a decomposed basic rock with large pyroxene phenocrysts. A section of this rock described by Nye (1923) contained dominantly serpentine with a little chlorite. The name websterite porphyrite was applied by Rosenbusch who considered that in its unaltered state, the rock would contain phenocrysts of bronzite or enstatite in a ground mass of pyroxenes. Specimen 637 from North Magnet contains large phenocrysts of enstatite that is largely altered to talc (?); the ground mass is composed of talc (?), sericite, quartz and chlorite. A similar rock (2183—alleged to be from the northern slopes of Mt. Bischoff) consists of enstatite crystals surrounded and in part pseudomorphed by talc (?). Fine anhedral quartz crystals and small fibres of chlorite are also present. This specimen probably represents part of the pyroxenite mass on the southern margin of the Magnet Dyke at the Persic Mine.

On the western side of the albite porphyrite at the Magnet Mine, there lies a decomposed pyroxenite. It is weathered to a brownish-yellow rock which contains decomposed crystals of pryoxene, similar to those of the eastern mass. In places this rock has an orbicular structure, containing abundant spheres with the same mineralogical composition as the general mass of the rock. The occurrences of the pyroxenites bounding the albite porphyrite appears to be limited to the Magnet and Persic Mine areas, the only areas of mineralisation along the "Dyke".

Another feature of the "Dyke" at the Magnet Mine is the inclusion of a large block of the Bischoff quartzites between the easterly pyroxenite and the albite porphyrite and a smaller block within the pyroxenite itself (Nye, 1923).

The origin of the "Dyke" is uncertain. Several features indicate an intrusive origin: (a) the complex nature of the "Dyke" at the Magnet and Persic mines, (b) the distribution of the "Dyke" along 5 miles of the Cambrian (?)-Precambrian contact and along what appears to be a discordant structure at the mine, (c) the composition of the pyroxenite, and (d) the inclusions of Bischoff quartzites within the "Dyke".

However, as Scott (1954) has demonstrated, there is a strong petrographical similarity of a large portion of the albite porphyrite with the spilites in the Magnet area and she concluded that the rock was volcanic. Also, Cambrian (?) volcanic breccias are apparently found adjacent to the "Dyke", specimens 35 N 8 and 35 N 22 from North Magnet and the Persic Section (labelled websterite and diabase porphyrite respectively) being breccias composed almost exclusively of volcanic fragments. The writers agree with Scott on the nature of the albite porphyrite but suggest the pyroxenites are intrusive.

Alteration of the Cambrian Lavas and the Magnet Dyke

These rocks have undergone a pattern of alteration that is characteristic of Cambrian volcanics elsewhere in Tasmania, generally involving the processes of albitization, chloritization, carbonation and silicification. The albite in amygdules and veinlets appears to be related to a late phase of the crystallisation of the flows, see also Solomon, 1960) and probably the chlorite, quartz and carbonate associated with the albite are also of similar (deuteric ?) origin. The cloudy albite forming phenocrysts shows no textures indicating its development by replacement of calcic feldspar and it appears to have crystallised at an early stage of lava solidification. The labradorite from the West Magnet mine shows no replacement by sodic feldspar but it does indicate the presence of at least some low-soda magma in the area.

The presence of albite and augite in ophitic texture in the King Island lavas (Scott, 1951b) is further support for a primary origin and a strong case can be made for the presence of a Na-rich magma during Cambrian volcanic activity.

Bradley (1954) considered the alteration of the Cambrian volcanics to be of Devonian age but it is likely to be Cambrian, because pebbles of altered volcanics occur in basal Ordovician sediments. Scott (1954) suggested that it resulted from the passage of heated, connate soluations rising from the geosynclinal column and causing redistribution of certain elements. The authors suggest that though albite is widespread it is confined to the volcanics and is of primary and/or deuteric nature.

(c) DEVONIAN ACTIVITY

A granite stock, known as the Meredith Granite, outcropping over about 120 sq. miles, extends from Parsons Hood in the south to within two miles of Waratah (Fig. 1). It has been mapped over a few square miles near Waratah and this part is essentially adamellite. It intrudes Cambrian (?) sediments and is pre-Tertiary but by analogy with other similar intrusions in Tasmania it is likely to be mid-Devonian to Carboniferous in age. To the north of this granitic mass are dykes of quartz-feldspar porphyry which intrude the Cambrian (?) sediments and appear to be related to the granite. Quartz-feldspar porphyries and topazised quartz

porphyries occur at Mt. Bischoff as a series of anastomosing dykes and sills, one of which apparently extends 3 miles north-east into Deep Creek (the granite mass indicated on the State Geological Map in Deep Creek appears to be a quartz porphyry dyke).

Adamellite

Two types of adamellite occur in the area examined; an even, medium-grained adamellite and a porphyritic adamellite, the porphyritic variety previously being considered as a late stage intrusive into the even grained granodiorite (Reid, 1923).

The even grained variety (30651, (e), (f) and (g) consists of orthoclase, oligoclase (approx. An_{30}) quartz and biotite as intergrown, generally euhedral crystals from 1 mm. to 3 mm. in length. Graphic interwrowths of quartz and orthoclase are common. Other minor components of the adamellite include hornblende, zircon, topaz and tourmaline. Modal analyses of three thin sections of this rock averaged 54.5% total feldspar, 36.1% quartz, 9.0% biotite and 0.5% accessory minerals. Some 20% to 30% of the total feldspar is oligoclase and the rest orthoclase.

The porphyritic variety is similar but contains large phenocrysts of oligoclase up to 2 cm. in length which in places show slight zoning. Modal analyses on four thin sections of this rock averaged 55% total feldspar (including 9% oligoclase phenocrysts), 34% quartz, 11% biotite and accessories. Thus the porphyritic and even-grained adamellites are compositionally similar and are probably variations within the granitic mass rather than distinctive bodies. This is supported by the field distribution which appears to be irregular and gradational.

Aplitic phases, consisting almost exclusively of quartz with minor orthoclase, contain large irregular clots of black fibrous tourmaline which constitute the greater proportion of the rock in places. Contact effects of the granite were not seen for lack of exposure.

Associated Quartz-Feldspar Porphyries

A dyke of quartz-feldspar porphyry extends north from the adamellite and outcrops between the junction of Seven-mile Creek and the Arthur Falls. It consists of large phenocrysts of orthoclase and quartz in a fine-grained ground mass of orthoclase, quartz, a little plagioclase and a ferromagnesian mineral which is probably hornblende. Associated with this rock is a more basic type which macroscopically appears to consist of phenocrysts of feldspar in a ground mass of feldspar and probably hornblende. The latter rock appears to occur mainly along the margins of the main quartz-feldspar prophyry dyke.

A further acid dyke probably occurs some 200 yards north of the Magnet Tram bridge over the Arthur River. The rock is extremely weathered, feldspar being the only recognizable mineral in a dominantly limonitic ground mass. Both dykes intrude Cambrian (?) sediments and contact effects are limited to slight baking for a few feet from the contact.

Quartz Porphyries at Mt. Bischoff

The most prominent feature of the geology of Mt. Bischoff is the profusion of altered porphyry intrusives within the Precambrian sediments. The majority of the porphyries occur as dykes from fifteen to one hundred feet in width, forming an overall radial pattern with preferential trends east-west and north-south, and steep dips to the north and west respectively. Large irregular masses also occur, for example on the summit, and to the north-east of Mt. Bischoff and also at Don Hill, the first two being marging points of several large dykes. Smaller, discordant intrusions of porphyry are common throughout the area, the majority apparently being offshoots from the main dyke system. Relatively thin sills of porphyry are also common, parteiularly at the junction of dolomite and Footwall shales (e.g. in the Brown Face and Slaughteryard Face). Alteration of the country rock by the porphyries is limited to slight baking for several feet from the contact.

Breccias composed of country rock fragments are consistently present on the walls of the porphyry dykes, the breccias varying from 2 to 20 feet in width. The fragments are angular or subangular, up to 2 inches in diameter, and are mainly in contact with each other. The matrix is largely crushed sedimentary material and fine grained porphyry. The contact between porphyry and breccia is irregular with small lenticular " splashes " of porphyry (both microscopic and macroscopic) extending into the breccia far several feet from the contact. Xenoliths of baked country rock are also common within the porphyry adjacent to the contact. In several cases, the structure as defined by the dolomite horizon is difficult to correlate across the dykes and in the case of the Western Dyke it is evident that there has been displacement along the line of the intrusion. This evidence, together with the occurrence of contact breccias of quite large dimensions, indicates that the porphyries were intruded into tensional openings containing fault breccias, and discounts the possibility of extreme brecciation during emplacement of the porphyries. The porphyries also exhiibt strong macroscopic banding, cross-bedding structures and small swirls which probably reflect flow movements in the partly crystalline porphyries during intrusion.

Within the general category of quartz porphyry there are several gradational varieties which depend on the subsequent alteration of a primary porphyry type rather than variations within the original parent magma. Remnants of unaltered porphyry occur in the southern portion of the White Face Dyke and Falls Creek, and are recorded by Reid (1923) from the western extremity of the Brown Face Dyke . Analyses of unaltered porphyries are shown in Table 3 (Nos. 1 and 7).

The porphyry from the southern portion of the White Face Dyke (e.g. 30617) consists of bipyramidal quartz phenocrysts up to 5 mm. in diameter with lath-shaped phenocrysts of a soft white substance in a fine ground mass. The laths are orthoclase almost completely altered to clay minerals (mainly kaolinite ?); X-ray powder photographs show strong similarities to orthoclase pattern but most of the lines are offset equal amounts in the

same direction, presumably due to alteration. D.T.A. curves confirmed the presence of kaolinite. The groundmass is largely quartz and sericite. Muscovite occurs sporadically throughout the rock as flakes up to 0.5 mm. in length. A modal analysis of a thin section indicated 59% groundmass, 25% quartz phenocrysts, 14% orthoclase phenocrysts and 2% muscovite.

The majority of the porphyries are topazised and contain only an insignificant proportion of original feldspar. These rocks are typified by specimens 30619 to 30629, 2173, 692, 693, 698, 700 and 702, an danalyses of typical samples are given in Table 3 (Nos. 2 to 6). The porphyries consist of a fine-grained ground mass of dominantly quartz and topaz with sporadic occurrences of sericite and fine threads of talc. Small crystals of fluorite and tourmaline are rarely present. The prismatic topaz has been referred to as pycnite (Reid, 1923). The topaz has refractive indices $\alpha=1.620$ $\delta=1.610$ and $2V=62$ indicating it has a molecular percentage OH/(OH+F) between 6 and 4 (Deer et al., 1962). High fluorine content is indicated in the partial analysis given by Reid, 1923. Quartz phenocrysts are abundant, generally ranging in diameter from 0.5 mm. to 2.0 mm. and in some instances reaching 5.0 mm. These phenocrysts are perfectly formed hexagonal crystals near the margins of the dykes but within the dykes are generally slightly corroded or possess a narrow rim of quartz in optical continuity with the phenocrysts, the outlines of which are still visible. Fluid inclusions are present, and in some instances common, in the quartz which also contains minute inclusions of zircon, muscovite and topaz. The portions of the dykes with non-corroded crystals represent the chilled marginal material. Lath-shaped cavities are also evident, these generally being lined with groups of radiating acicular crystals of topaz growing inwards from the cavity walls; they were probably feldspar phenocrysts (Plate II, Fig. 3). Topaz is also evident as acicular crystals associated with irregular aggregates of anhedral quartz crystals in optical discontinuity, and as partial rims around corroded quartz phenocrysts. Sulphides are generally abundant, occurring as finely crystalline particles; many occurrences form lath-shaped aggregates, probably replacing feldspar (Plate II, Fig. 4). Pyrite is the dominant sulphide mineral although arsenopyrite occurs sporadically throughout the porphyries, and pyrrhotite is common in porphyry sills on the contact of replaced dolomite and slate Finely crystalline sulphides are also found associated with the quartz-topaz ground mass. Oxidation of these sulphides has occurred near the surface and accounts for the high proportion of Fe_2O_3 in several of the analyses. Cassiterite is also present in the porphyries as fine granular crystals replacing feldspar laths and rarely as well-formed zoned crystals up to 0.5 mm. in diameter.

Table 3

Chemical analyses of porphyries from Mt. Bischoff

	1	2	3	4	5	6	7
SiO_2	73.78	66.92	70.16	68.98	68.64	72.30	79.69
TiO_2	0.06	0.06	0.09	0.05	—	trace	+
Al_2O_3	14.35	19.88	21.69	19.96	19.38	17.17	13.49
Fe_2O_3	0.61	trace	0.14	1.05	0.21	trace	0.14
FeO	1.57	0.64	0.35	0.19	0.29	0.58	2.08
MnO	0.09	trace	trace	trace	trace	trace	+
MgO	0.62	0.24	0.22	0.28	0.31	0.29	0.60
CaO	0.44	0.36	0.20	0.20	0.68	0.28	0.46
Na_2O	0.40	0.05	trace	trace	trace	trace	0.08
K_2O	6.01	0.07	0.07	trace	trace	0.37	2.71
H_2O+	2.15	0.98	0.77	0.69	0.96	1.04	+
H_2O-	0.12	0.11	trace	0.05	0.24	0.19	+
P_2O_5	trace	trace	trace	trace	trace	trace	+
CO_2	+	+	+	+	+	+	+
FeS_2	trace	6.62	2.19	4.86	5.85	3.91	+
Ca	+	0.02	trace	0.01	0.01	0.01	+
SnO_2	+	0.07	0.13	0.16	0.08	0.16	+
F	+	6.48	6.63	6.86	6.46	6.15	+
Total	100.20	99.77	99.94	100.39	99.86	99.94	99.64

Localities—

1, 2, 3—White Face Dyke.
4, 5, 6—Western Dyke.
7 —White Face Dyke.

Analyst for 1-6.—Dept. of Mines, Assay Laboratories, Tasmania, 1962.

Analyst for 7. —A. D. Mackay (in Reid, 1923).

Unusual varieties of porphyry occur along the North Valley road (30630 a and b). These are quartz-topaz porphyries but contain abundant rosettes of muscovite in lath-shaped aggregates. A further variety (30631) contains a higher proportion of pyrite cubes, several of which enclose quartz phenocrysts, thus indicating crystallization after the quartz. Large phenocrysts of muscovite are also common in this rock. Muscovite is also common in a porphyry dyke on the contact of the Bischoff sediments with Cambrian (?) sediments to the west of Waratah (30633); this porphyry consists dominantly of sheared quartz phenocrysts with elongate aggregates of sericite in a fine quartz-sericite ground mass. It is unusual in that it has been sheared.

The White Face Dyke (see Fig. 4) was examined in some detail as it provides an opportunity of studying the gradation from a quartz-feldspar porphyry to a quartz-topaz porphyry. It was sampled closely from just south of the Bischoff open cut northward into White Face, i.e., from unaltered to intensely altered material. The unaltered quartz-feldspar porphyry grades into a rock with a felsitic ground mass and idiomorphic quartz phenocrysts and lath-shaped masses of siderite, pyrite and fluorite with some remnants of orthoclase (30618). Biotite and muscovite are also present, generally being associated with talc as minor constituents of the ground mass. This rock then grades into a quartz-topaz porphyry. The intermediate zone described above is only a few feet wide. Analysis 1 (Table 4) is of unaltered porphyry and analyses 2 and 3 are of quartz-topaz porphyry. Aanalyses 4, 5 and 6 are from the Western Dyke, taken at intervals of 2-300 ft., No. 4 being from the old Haulage, No. 5 near Slaughter-yard Face and No. 6 just south of Mt. Bischoff peak. Little variation is noted although potassium is more abundant in No. 6 which is the most westerly sample, and may indicate the occurrence of minor original feldspar amay from the main centre of mineralization.

The occurrence of a quartz-feldspar porphyry towards the limit of mineralization at Mt. Bischoff and the consistent occurrence of topaz, fluorite, sulphides and cassiterite in lath-shaped cavities and in the ground mass is strong evidence that the latter minerals are present as pseudomorphs after feldspar during alteration. This was also suggested by Dunn (1922), who considered that the alteration took place homogeneously in a crystal mush prior to emplacement. If this hypothesis were correct, it would be expected that the proportion of topaz and other replacement minerals would be constant throughout the dyke. Sections of porphyry taken across the Western Dyke were examined, 30625a and d being marginal samples and 30625 b and c samples from near the centre of the dyke. Modal analyses of these sections (as percentages) are given below. One thousand counts mere made on 4sq. cm. to determine the phenocryst-ground mass ratio, 1,000 counts on the same area for the composition of the ground mass and 1,000 counts for the composition of the phenocrysts.

	30625a	30625b	30625c	30625d
Ground mass—				
Topaz	41.8	27.6	24.0	39.4
Quartz	29.6	54.8	45.0	33.2
Total Ground mass	71.4	82.4	69.0	72.6
Phenocrysts—				
Topaz	19.0	8.0	14.6	7.8
Quartz	7.4	9.2	14.0	5.8
Pyrite	1.2	0.2	2.4	—
Fluorite	0.2	—	—	—
Miscellaneous	0.8	0.2	—	13.8
Total phenocrysts	28.6	17.6	31.0	27.4

It is evident that the marginal zones of the porphyry contain more topaz and other alteration products than the central zone, even allowing for standard deviations of several percent in the modal anlyses. This suggests that the pneumatolytic vapours or solutions were introduced along the open brecciated walls of the dyke and were not active within the magma prior to emplacement, as imagined by Dunn. Topaz thus replaced the feldspar in the ground mass and phenocrysts while the porphyry was in a solidified or perhaps a semi-solidified state, with crystallized phenocrysts of orthoclase and quartz in a molten felsitic ground mass.

The occurrence of muscovite, fluorite, siderite and talc pseudomorphing feldspar in place of topaz at the extremities of the mine area, and the occurrence of unaltered quartz-feldspar porphyry near Don Hill and in Falls Creek, suggest that a temperature gradient may have existed in the area with extensive topazisation in the areas of highest temperature towards the centre of Mt. Bischoff.

In places, alteration has been so extensive that the original texture of the porphyry no longer exists and the rock can only be distinguished as an alteration product by a gradation into recognizable porphyry. In the White Face, along the walls of the dykes, the topaz has replaced even the quartz, producing spherulitic aggregates of topaz in association with euhedral to anhedral crystals of cassiterite, many of which show marked zoning (e.g. 694 and 698). The spherulitic topaz comprises a central, granular aggregate surrounded by radiating prisms (Plate II, Fig. 4) and needles of topaz, and is rarely associated with radial blue tourmaline crystals.

The porphyries have also been totally replaced in the White Face and near the Main Tunnel entrance by tourmaline, fluorite and siderite. These rocks (30634 a to f) generally comprise large crystals of fluorite several mm. in length, which contain inclusions of sericite and siderite, these being bounded in places by sheaf-like masses of muscovite, producing a halo effect. The fluorite is completely surrounded and "intruded" by aligned acicular crystals of tourmaline which exhibit marked pleochroism from blue to colourless. Coarse crystals of siderite also occur and are themselves riddled with a profusion of acicular crystals of tourmaline. In specimen 30634 d moderately thick veins of sheaf-like muscovite occur in association with the tourmaline.

The tourmaline is dark green in hand specimen and has refractive indices $\alpha=1.6580$, $\delta=1.6325$ ($\delta=0.0255$).

An analysis given by Reid (1923, p. 55) is as follows:—SiO_2:36.86, Al_2O_3:36.72, FeO:5.66, MgO:3.92, MnO:0.66; CaO:0.34, Na_2O:3.57; K_2O:1.11; B_2O_3:10.56; F:0.61; total: 100.01. Though no H_2O is given the analysis indicates a composition somewhere between a schorl and dravite type and this matches the optical properties.

The occurrence of these totally altered porphyries is limited and is probably due to very local influxes of pneumatolytic vapours or solutions, particularly on the margins of the porphyry dykes.

In summary, the sequence of events at Mt. Bischoff is considered to have commenced with the diapiric injection of a narrow cupola of granitic material into the hinge of the Bischoff Anticlinorium, the cupola probably being connected to underground extensions of the Meredith Granite (Fig. 3). The diapiric upthrusts produced tensional stress in the roof sediments with the formation of a radial pattern of tension faults splaying outwards from the focus of injection. These tensional openings were then intruded by quartz porphyry dykes, several of which protruded along selective stratigraphic horizons as sill-like extensions. Associated with the emplacement of the porphyries, pneumatolytic vapours or solutions rose up from the cupola along the open channel-ways of the marginal brecciated walls of the porphyries, producing widespread replacements of primary feldspar by topaz, tourmaline, fluorite, sericite and cassiterite and finally, by pyrite, arsenopyrite, pyrrhotite and cassiterite.

As recognized by Twelvetrees and Petterd (1897) the quartz porphyry dykes are similar to the elvans of Cornwall, England. In this area, folded Palaezoic slates and sandstones, and later granitic stocks, are intruded by greisenized quartz porphyry dykes (MacAlister, 1908; Lindgren, 1933; Llewellyn, 1946; Dewey, 1948; and Dunham, 1952). The tin deposits are limited areally to the foci of intrusion with copper and lead-zinc lodes in the surrounding area. Greisenization has been extreme in the Cornwall deposits, the granite along the lode walls being altered to quartz, muscovite and topaz as aggregates pseudomorphing partly altered feldspars. Fluorite is present in places and the secondary quartz is filled with liquid inclusions. The quartz porphyries have also been altred to quartz, tourmaline, topaz and fluorite with kaolin locally. The alteration is limited to areas of mineralization and is not widespread through the granite.

Kaolinization of the granite has occurred over quite extensive areas and is considered a relatively low temperature effect, as in the marginal zones at Mt. Bischoff. In the porphyries there has been an addition of iron, tin, fluorine and boron as at Mt. Bischoff but potassium remains high, probably due to the formation of muscovite. It is probable that similar hydrothermal and pneumatolytic alteration processes occured both at Mt. Bischoff and Cornwall, indicating a similar granitic source.

(d) JURASSIC ACTIVITY

Dolerite

Two bodies of Jurassic dolerite intrude Cambrian (?) sediments in the area. The largest occurs north of the Magnet Mine and is a dyke-like mass extending for about 1500 feet in a north-easterly direction. The second mass is a small intrusive just west of the Magnet Tram, to the north of the contact of basalt and Cambrian (?) sediments. Thin sections of these rocks (715 and 35 G.2-Mines Dept.) show augite and labradorite exhibiting an ophitic to doleritic texture, the individual crystals occurring up to 1.5 mm. in length. Between the larger crystals is a fine ground mass of quartz and feldspar with some fine interstitial magnetite.

The dolerite is identical to phases of the dolerite sills intruding Permian and Triassic rocks in south-eastern Tasmania.

(e) TERTIARY ACTIVITY

Basalt

A basalt sheet, some 50 to 150 feet thick, occurs extensively over the plateau area between Waratah and Guildford, on the Magnet Range, and as small remnants elsewhere in the area. It generally overlies Tertiary terrestrial sediments, the base being at an elevation of 1900 to 2000 feet.

The basalt (30652 and 35 G.6 Mines Department) generally consists of a fine intergrowth of labradorite and augite, up to 0.3 mm. in length, with interstitial calcite and magnetite. Olivine is generally present, occurring as larger crystals up to 2 mm. in diameter that have been slightly serpentinized. Tachylyte also occurs in places, specimen 35 G.7 (Mines Department) consisting of large particles of green glass, up to 6 mm. in length, with a ground mass of labradorite, calcite and augite. In places the basalt is extremely vesicular and in some cases is scoriaceous.

Three thin basaltic dykes occur in the Arthur River intruding Cambrian (?) sediments; one about 1½ miles upstream and one 2 miles downstream from the confluence with the Waartah River, and one about 1½ miles upstream from the old Magnet Tram bridge. These may represent 'feeders' for the main basaltic sheet. A specimen from the basaltic dyke near the Magnet Tram (30652b) contains phenocrysts of labradorite in a ground mass of labradorite, purplish-brown augite and magnetite. Magnetite also occurs abundantly as elongate blebs in the cleavage cracks of the labradorite phenocrysts. Amygdules of chlorite and a fibrous zeolite are also present. Olivine is apparently absent.

STRUCTURE

The dominating structural feature of the district is the E-W trending Bischoff Anticlinorium within which the Precambrian rocks outcrop. This structural trend is unusual in NW Tasmania, where the majority of boht large and small scale structures trend NW or NNE (Carey, 1953; Solomon, 1962).

The Waratah district is supposed to lie between early Palaeozoic geanticlinal ridges, the margins of which trend about NNE in NW Tasmania. Early Tabberabberan folding is thought to have been

controlled in trend by these pre-existing surfaces, and later folding, on NW trends, is thought to be due to some "external" cause (Solomon, 1962).

The E-W structures may reflect some much earlier deformation, the trends of which have locally altered the dominant Tabberabberan directions. A pre-Cambrian deformation is indicated by the microscopic fabric in the Precambrian (?) sandstones and by other features to be described.

Devonian Structures

Folding

The form of the Bischoff Anticlinorium is indicated by the map of the Precambrian inlier (Figs. 1, 2 and 3). Its wavelength is approximately 5 miles and its amplitude approximately 2 miles. It plunges gently to the west and probably also to the east, to form an elongate dome. The contact between Bischoff quartzites and slates and the Cambrian (?) sediments on the southern flank shows apparent concordance, with minor faulting, while the northern flank is largely occupied by the Magnet Dyke which extends along a possible fault contact between the two sequences. The main zone of porphyry dykes is concentrated in the axial surface of the anticlinorium and it is suspected that a granite cupola exists beneath Mt. Bischoff.

Smaller folds with wavelengths of 100 to 1,000 feet occur on the anticlinorium; the majority have been mapped by using the base of the dolomite as a marker horizon. These folds have been outlined fairly accurately in the Bischoff mine workings and here they are typically associated with sub-longitudinal tensional faults that tend to obliterate limbs of the folds. In the Brown Face syncline the faulting is slightly oblique to the fold axis and as a result the dolomite base has a "keel" form. The folds of the Bischoff mine have very shallow plunges, dominantly to the west. Previous interpretations of the plunge of these folds (Knight, 1953, Hall & Solomon, 1962) have not recognized the importance of slightly oblique faulting producing keel-like structures. The exposed extent of these folds is limited by NNW faults, almost transverse to the fold axes (Fig. 4).

The Main Tunnel of the Mt. Bischoff mine extends from the north to the south side of the mountain and, although partly filled in, it provides a sub-surface cross section through a zone of minor folds on the anticlinorium. Mapping of the tunnel shows fairly gentle undulations below structures which at the surface have considerable amplitude, indicating that the minor folds on the anticlinorium die out within depths approximating to the wavelengths of the folds.

North East Folds

Distorting this general W trend of folding are smaller folds which show a variable trend, with a distribution of axial surfaces around 60°M. These NE folds and also the larger W structures are highlighted by the plot of axial surfaces shown in

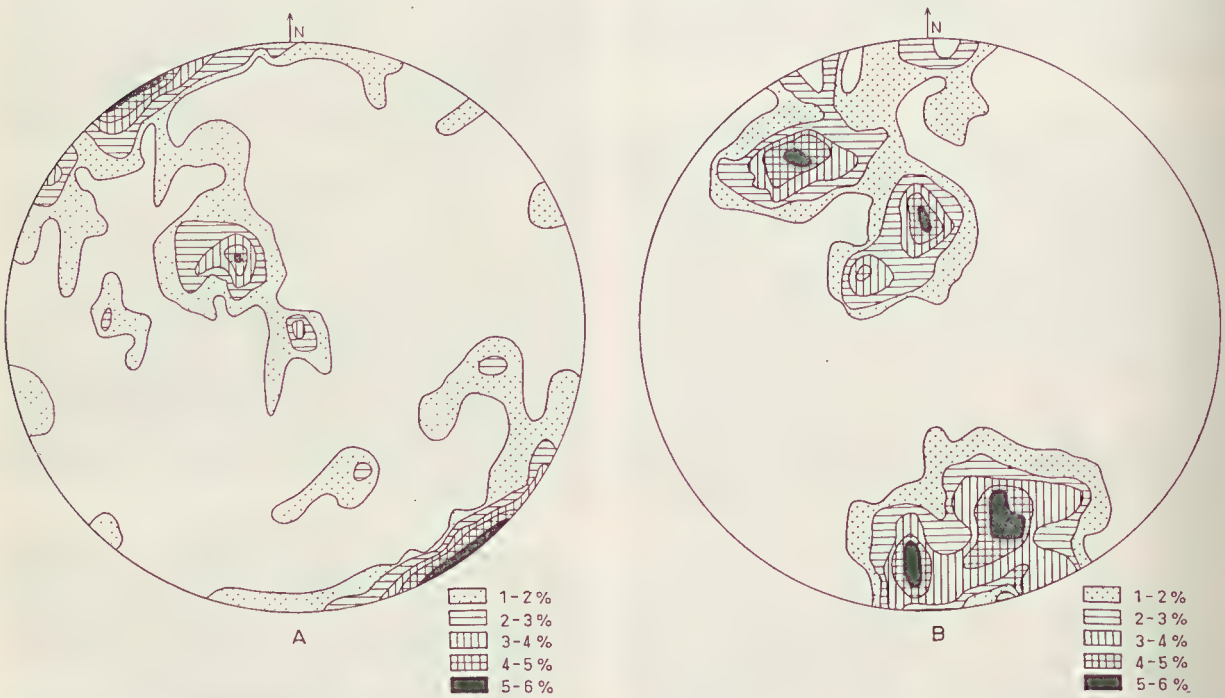

FIG. 7.—Stereographic projection (lower hemisphere) of:—
(*a*) Axial surfaces of folds.
(*b*) Poles to bedding planes.

Fig. 7a, also by the plot of several hundred bedding readings taken between Don Hill and the Arthur-Waratah River confluence (Fig. 7b). These folds which vary in wavelength from 2 to 100 feet, vary in plunge from northerly to southerly. The axial surfaces generally dip towards the SSE on the southern limb of the anticlinorium and towards the NNW on the northern limb, although there are minor variations. The folds are restricted in exposure to areas of thin-bedded shales and quartzites and are abundant in the Mt. Bischoff mine where they are so intense as to almost obliterate the W folding. Small folds belonging to this group are also evident in thin bedded mudstones of the Cambrian (?) sequence. The folds display all variations from a concentric to a similar style of folding, although a concentric style is dominant.

A small group of folds, of similar wavelength and style to the previously mentioned folds, occur with a NNW to NW trend. A large proportion of the folds are restricted to areas adjacent to NNW to NW faults, and were probably produced by local fault movements.

Generation of Folds

There is no reliable indication of the order of super-imposition of the two main fold generations, though it is suspected that the small wavelength folds are later than the larger.

Faulting and Jointing

The majority of known Devonian faults appear to be tensional and either of W or NNW trend. A plot of the poles of faults other than of W trend indicates a variation in strike from between 330° and 350°M, with the majority at 340°M. These faults dip fairly consistently to the west at high angles, though some are vertical and a few dip very steeply east. An important fault of this group displaces the minor W folds on the Bischoff anticlinorium. Other parallel faults cut the porphyry dykes and are mineralized, indicating a post-intrusive age. In a few, shearing of the ore indicates later movement on the pre-existing faults.

Well developed joints, with 6 inches to 2 feet spacing, strike consistently at 340°M and these joints in many cases carry quartz and cassiterite. They occur in porphyry dykes and in both Cambrian (?) and Precambrian sediments. They appear to be later than the folding and dyke intrusion and related to the mineralization phase.

The normal faults accompanying folding, with longitudinal or slightly transverse trend, have already been described.

As previously mentioned the porphyry dykes were probably injected into a set of radial tension fractures formed by rise of a cupola-like mass into the Bischoff Anticlinorium. Some movement along these fractures is indicated by the presence of breccias and by displacements of marker horizons across the dykes. The displacements are estimated to be less than 100 feet. Fissure veins several feet in width occupy tension fractures, some of which appear to be related to the radial prophyry pattern and others to the 340°M trend.

The displacements developed by the north-south folds inferred by Knight (1953) appear to be due to movement on the 340°M faults.

Pre-Devonian (?) Structures

A number of small scale folds and thrusts are confined to the Precambrian sediments and may be related to some pre-Tabberabberan tectonic phase. Isoclinal folds with wavelengths of several feet are confined to relatively thin-bedded quartzites of the Bischoff quartzites and slates. The folds trend 80°M to 90°M and occur within the limbs of the minor, E-W trending folds. The folds plunge shallowly both to the east and west, no steeply plunging folds being observed.

Chevron folds, with a wavelength of 1 to 10 feet are limited to the marginal zones of the Precambrian (?) core, occurring commonly in the Arthur River and Magnet Creek near the confluence of the two streams, and more rarely on the southern contact of the south-east slopes of Don Hill. Up to twenty chevron folds with subparallel vertical axial surfaces have been observed in a single outcrop in the Arthur River area. The folds, which trend between 40°M and 50°M and plunge steeply to the south-west and north-east, occur exclusively in thinly bedded quartzites and shales.

Small recumbent folds, generally with a wavelength of approximately one foot, occur sporadically throughout the area. They appear limited lithologically to thinly bedded shales and structurally to local areas where the isoclinal folding has been less intense than elsewhere. Cascades of several of these folds with slightly variable axial surfaces occur in places, although single folds within shale bands are more common.

Small monoclinal 'warps' are a distinctive feature of the deformation of the Bischoff quartzites and slates. They occur on a small scale throughout the area, generally in shales and rarely in quartzites. The axial surfaces of the monoclinal bends are locally dependent on the orientation of larger folds and are variable throughout the area.

At this stage it is not possible to be certain of distinguishing between pre- and post- consolidation structures, particularly in rocks with a lack of cleavage associated with the folds.

Insufficient structural work has been done to firmly date the age and sequence of development of this group of folds. The quartz microfabric in the Bischoff quartzites indicates an early movement phase and this is further indicated by the presence of isolated blocks of quartzite within shales in parts of the Bischoff succession. These blocks are generally elongate parallel to bedding and taper at their extremities with shales "flowing" around and enclosing the blocks. In most cases it has been impossible to determine whether these blocks represent fold mullions or boudins, but in some cases they appear to be part of a fragmented bed of quartzite.

Tertiary Faulting

The Tertiary terrestrial sediments are generally horizontal throughout the area although on the south-western flank of Don Hill they dip to the south-west at angles up to 50°; these steep dips,

and associated folds, may be due to late Tertiary faulting but are more probably due to compaction of the Tertiary sediments against the bedrock cliffs.

The linear nature of the Waratah River, as described in a previous section, is suggestive of a possible Tertiary fault trend.

MINERALIZATION

Mt. Bischoff is situated in a strip of dominantly low grade silver-lead-zinc mineralization which trends north-north-easterly and lies on the north-west flank of the large granodiorite mass centred at Mt. Meredith. Tin mineralization occurs within the granitic mass to the south of the Waratah-Corinna Road, in association with quartz porphyry dykes at Mt. Bischoff, and adjacent to reported quartz porphyry dykes at the Cleveland Mine.

Tin Mineralization

Granodiorite

Mineraliaztion is confined to aplitic and pegmatitic bodies within the main granodiorite mass. The ore bodies are small and largely lenticular in shape and they comprise arsenopyrite, molybdenite, pyrite, chalcopyrite, sphalerite and cassiterite in a gangue of green, fluorine-bearing mica. Quartz and tourmaline are commonly present in association with the ore. The lodes do not appear to have any distinct structural control.

Mt. Bischoff

At Mt Bischoff, tin mineralization has been more localised and more intensive than in the granodiorite. The tin occurs in a number of widely differing types of ore body, which are limited to a circular area of 2000 feet radius from the centre of the mountain. The ore bodies comprise (a) a large replacement body in dolomite, (b) numerous vein deposits, (c) replacements of porphyry and (d) incrustations on joint faces, in and adjacent to porphyry dykes.

(a) The main ore body was formed by replacement of the dolomite bed which occurs towards the top of the Bischoff quartzites and slates. This bed, which was probably folded prior to mineralization, has been largely replaced by pyrrhotite, pyrite, talc, quartz and an iron-manganese- magnesium carbonate. Typical analyses of this secondary carbonate are given in Table 4. Within the replaced dolomite are semi-continuous layers of apparently sheared talc which are possibly secondary after tremolite. This alteration probably results from metasomatic alteration of the dolomite along shear zones.

At the eastern end of the Brown Face open cut is an outcrop of dark gren and yellowish rock that is composed of chondrodite partially replaced by serpentine (chrysotile?) and pyrrhotite. It is colourless and non-pleochoic, has $2V=72+$ve, $\alpha=1.615$, $\beta=1.635$, and is twinned on (001) and also on other composition planes (not yet determined). The identification of chondrodite was confirmed by X-ray diffraction.

The distribution of mineralization is extremely irregular within the body, some sections comprising massive sulphides while others are virtually sulphide free. The distribution of the sulphides themselves is more regular, pyrrhotite being the dominant sulphide towards the centre of mineralization, while pyrite and sphalerite are more common to the north and south. Mineralization was apparently confined to a relatively small area, as unmineralized dolomite crops out to the south in Happy Valley and to the north, on the northern slopes of the Waratah River valley.

The tin, dominantly as cassiterite, occurs throughout the replacement body and although microscopically associated with gangue minerals is most abundant in zones of high sulphide concentration. These zones are commonly slightly oblique to the margins of the dolomite bed and occur in different structural environments throughout the mine area. In general they occur within south-dipping limbs of the dolomite with local concentrations adjacent to fault walls. The zones of highest concentration may represent lode channels for the mineralization.

Table 4

Analyses of Mineralized Dolomite, Mt. Bischoff

	I	II
SiO_2	6.00	1.00
Al_2O_3	0.95	1.56
Fe_2O_3	—	—
FeO	2.56	12.72
MnO	0.92	13.26
MgO	11.75	14.46
CaO	21.08	3.20
Na_2O	—	—
K_2O	—	—
$H_2O\pm$	7.00	6.40
CO_2	49.64	47.40
F	—	—
FeS	—	—
SO_3	—	—
	99.90	100.00

I.—From Happy Valley Face (Reid, 1923, p. 86).
II.—From Mt. Bischoff (Reid, 1923, p. 86).

Stillwell (1945) has divided the ore into three dominant types: (i) carbonate-sulphide ore, (ii) massive pyrrhotite ore and (iii) pyrrhotite-talc ore.

(i) The carbonate-sulphide ore consists essentially of coarse grained carbonates, grain diameter up to 5 mm., containing irregular splashes and veinlets of sulphides, dominantly pyrrhotite, pyrite and arsenopyrite. Small blebs of chalcopyrite and galena and crystals of cassiterite occur rarely in the sulphides. Small clusters of cassiterite up to 0.25 mm. in diameter occur more commonly in the coarse carbonate, and are partially coated with a thin film of chalcopyrite and stannite.

(ii) The massive pyrrhotite ore is dominantly pyrrhotite with colloform masses of pyrite and a little marcasite. Irregular threads of chalcopyrite, bismuthinite and galena are also present, and Stillwell reports minute grains of stannite (0.01 x 0.005 mm.) occurring in chalcopyrite veins. Minor proportions of quartz, fine platey talc, fine carbonate, fluorite and zeolite are embedded in the pyrrhotite.

(iii) The talc-pyrrhotite ore comprises alternate bands of pyrrhotite and talc up to 2 mm. wide. The pyrrhotite bands are crossed at irregular intervals by carbonate and pyrite veins, and contain rare cassiterite crystals. Small chalcopyrite veinlets occur on the boundary of pyrrhotite and talc masses.

(b) Vein deposits carrying cassiterite occur throughout the mountain. These lodes fill fractures which in places displace porphyry dykes and cut the pyrrhotite replacement body; hence they are considered a later phase of mineralization than the dolomite replacement. The veins have strike lengths up to 2,500 feet and dip length up to 1000 feet and they pinch and swell along both dip and strike. The veins also commonly branch and converge forming a complex system of subsidiary ore bodies. The veins comprise cassiterite, in association with pyrite, pyrrhotite, arsenopyrite, sphalerite, chalcopyrite, galena, jamesonite, bismuthinite, wolframite, stannite, quartz, siderite, tourmaline, fluorite and topaz, the relative proportions of these constituents varying considerably from one vein to another (see Stillwell, 1943). Apart from the major veins with an average width of 2 feet, there are subparallel sets of minor veins, some 1 to 2 inches in width, which commonly consist of quartz and cassiterite. These are generally too small to be economic.

The veins vary in strike from NNW to WNW and generally dip steeply to the west. This is also true of the minor vein deposits.

(c) The quartz porphyry intrusives have been mineralized throughout most of the mine area by topaz, tourmaline, fluorite, pyrite, pyrrhotite and cassiterite; these minerals generally pseudomorph feldspar. In places the proportion of this disseminated cassiterite ore was high enough for quarrying of the porphyry to prove economic.

(d) Well crystallized crystals of cassiterite, with a little quartz and tourmaline, also occur as incrustations on joint faces within the porphyry and in the quartzites and shales, for up to 15 feet on either side of the intrusives. Where the joint frequency is considerable, the rocks have been mined by open cut methods.

Replacement of the dolomite and quartz porphyries probably involved a protracted period of alteration dependent to a large extent on temperature gradients and variations in gass and water pressure. However, the mineral assemblages formed at Mt. Bischoff can be satisfactorily divided into two temperature-dependent groups which are partially gradational. The higher temperature mineral assemblage consists of topaz, tourmaline, cassiterite, muscovite and some fluorite which largely replaces the quartz porphyries. This phase represents the introduction of fluorine and boron-rich vapours which were largely confined to high temperature zones delineated by the quartz porphyries.

Equivalent alteration of the dolomite horizon appears limited, although it is probably represented in the formation of chondrodite, minor topaz and tourmaline and possibly tremolite. Replacement of the dolomite horizon involves widespread magnesium metasomatism with alteration of virtually pure dolomite mineral (Table 2) to magnesium-rich carbonates and talc (Table 5). The dominant assemblage is sulphides, talc, carbonates, "serpentine", sericite, fluorite and cassiterite probably representing a slightly late more widespread, aqueous phase of mineralization under lower temperature conditions. Replacement of chondrodite by "serpentine" and possible replacement of tremolite by talc confirm this sequence.

Conformable pyrrhotite-pyrite-cassiterite bodies similar to that at Mt. Bischoff occur at Renison Bell and Mt. Cleveland (25 miles south, and 8 miles south-west, of Mt. Bischoff respectively).

The deposits at Renison Bell (Fisher, 1953; and Hall and Solomon, 1962) are gently dipping pyrrhotite sheets, up to 200 feet thick, or steeply dipping fissure lodes comprising pyrite and pyrrhotite. They occur in a Cambrian perhaps partly late Precambrian, succession of mudstones, greywackes, sandstones and dolomite, the pyrrhotite replacement bodies occurring mainly in a succession containing dolomites. The sediments have been folded into NW-trending anticline with normal faulting both parallel and oblique to the fold axis. Greisenized quartz porphyry dykes cut the sediments near the anticlinal hinge. The associations of greisenized quartz porphyry dykes with conformable pyrrhotite replacement bodies in Cambrian-Precambrian successions containing dolomite at both Mt. Bischoff and Renison Bell suggest a similar origin for the two deposits.

At the Mt. Cleveland Mine (Reid, 1923; Hall and Solomon 1962) pyrrhotite sheets replace certain beds in a sequence of Cambrian (?) sediments. As at Mt. Bischoff and Renison Bell, both replacements and fissure veins carrying cassiterite occur. The ore bodies comprise pyrrhotite, pyrite, chalcopyrite, arsenopyrite, quartz and cassiterite. Reid (1923) records that there are quartz porphyry dykes intruding the sediments in this area though later workers have failed to find the dykes. The Cleveland ores are basically similar to those at Mt. Bischoff but occur in a higher stratigraphic horizon and have a less obvious relationship to porphyry dykes.

Silver-Lead-Zinc Mineralization

Isolated, small silver-lead zinc veins are common throughout the Waratah District, intersecting both the Bischoff quartzites and slates and the Cambrian (?) sediments. The largest deposit occurs at the Magnet Mine as a vein, some 10 to 15 feet in width, on the contact of albite porphyrite and websterite poryhyrite of the Magnet Dyke (Fig. 6). In depth this lode has a bifurcated structure with the main body of ore occurring at the junction of the two lodes, which were considered as intersecting shears by Nye (1923), Cottle (1953) and Edwards (1960).

The lode is dominantly ankerite with bunches and veinlets of galena and sphalerite and lesser amounts of arsenopyrite, pyrite, boulangerite, pyrargyrite, tetrahedrite and traces of chalcopyrite in a gangue of manganosiderite and ankerite (Edwards, 1960). Chalcopyrite occurs dominantly as segregation bodies in sphalerite, and pyrargyrite and tetrahedrite as drop-like inclusions in galena. Crustification textures are extremely common,

with all sulphides interlayered with manganosiderite. Cockade textures, developed about fragments of brecciated and serpentinized pyroxenite, are also common. Strong shearing and brecciation preceded the close of ore deposition with the production of elongate bent and brecciated fragments of galena and sphalerite which were later cemented by ankerite. This shearing and brecciation supports the theory of ore control by intersecting shears. Edwards (1960) also suggests that the mode of occurrence of the Magnet ore indicates an epigenetic origin and that the crustification and cockade textures indicate that the ore was, at least in part, deposited in open spaces.

The southern margin of the Magnet Dyke has also been a host for ore deposition, to the north-east of Magnet. A small lead deposit occurs at the Persic Section on the contact of Bischoff quartzites and slates with the Magnet Dyke. It may be significant that pyroxenite occurs on the southern margin of the dyke at this locality and also at Magnet. The Persic lodes are small, irregular and uneconomic, generally occuring as small splashes of galena and siderite within the country rock and not as a distinct vein as at the Magnet Mine. Small veins of quartz and carbonate which contain traces of copper and silver, also occur on the contact of Bischoff quartzites and slates and the Magnet Dyke at Fawkner's Show (North-east of the confluence of the Arthur River and Magnet Creek).

Small pockets of silver-lead-zinc mineralization are also common throughout the Waratah District away from the Magnet Dyke. The majority of these deposits are small, irregular uneconomic veins, the most extensive deposit occuring at the Silver Cliffs Mine to the north-west of Mt. Bischoff. This well banded lode consists of galena, jamesonite, sphalerite, pyrite and minor boulangerite in a gangue of quartz and siderite. Similar small lodes occur on the northern slopes of the Arthur River (Fig. 1). Small lodes of sulphantimonides, jamesonite, stibnite, berthierite and boulangerite occur in Tinstone Creek to the south-west of Mt. Bischoff and are probably related to the silver-lead-zinc deposits, which commonly contain a high proportion of jamesonite. This group of prospects forms a "halo" of lead-zinc mineralization around the Mt. Bischoff tin deposit.

A genetic relationship between the silver-lead-zinc deposits and the Mt. Meredith granodiorite mass is suggested by the occurrence of the deposits in a belt on the north-west flank of the mass and their general lack of areal conformity with other igneous masses in the area. Silver-lead-zinc mineralization probably occurred during the Devonian metallogenetic epoch along fractures in the roof sediments over a large granodiorite batholith which is now partially exposed. Tin mineralization was confied to aplitic and pegmatitic bodies within the granodiorite and an area cut by numerous porphyry dykes at Mt. Bischoff.

Determination of formation temperatures of the lodes in the Waratah District using the pyrrhotite and sphalerite geothemometer (Arnold and Reichen, 1962 and Kullerud, 1953) indicate a local temperature "high" at Mt. Bischoff with zonation outwards from the centre of intrusion. A lower, irregular temperature gradient existed over the remainder of the area, probably locally controlled by the granodiorite batholith.

The spatial association of sulphide-cassiterite and later stage silver-lead-zinc ores is a characteristic also of the Renison Bell and Cleveland mines and is in fact, typical of many tin-rich provinces. Bilibin(1955) suggestes, from a study of similar deposits in the U.S.S.R., that these sulphide-tin ores generally are related to the "late stages" of geosynclinal development, involving the intrusion of small granitic porphyries into fractured zones. He finds the majority of these deposits are Mesozoic or Tertiary.

Oxidation of the Orebodies

Gossans developed during the Tertiary over several outcropping sulphide orebodies. Indigenous gossan at the Magnet Mine is dominantly limonitic with bands of secondary minerals such as cerussite and pyromorphite. Gossans derived from pyrrhotite formed extensively over Mt. Bischoff. Though largely removed by mining, old reports indicate that they were a mixture of indigenous and exotic types. Pyrrhotite is very unstable in temperate conditions and breakdown resulted either in development of a friable limonitic crust with cassiterite concentrated at the base, or in complete removal of iron and sulphur, leaving a cassiterite or cassiterite-quartz sand on the surface. Where the orebodies cropped out on hillsides the cassiterite-quartz sand travelled down slope to form extensive eluvial and alluvial deposits. The spread of the exotic limonite was retarded to some extent by the presence of the dolomite bed but much of the dolomite was removed by the abundant sulphuric acid, resulting in further cassiterite concentration.

GEOLOGICAL HISTORY

Shallow water deposition of well sorted sands, silts and muds began during the Upper Precambrian. Chemical precipitation of dolomite with some contemporaneous deposition of muds and silts occurred towards the end of sedimentation with subsequent deposition of silts. Preconsolidation tectonics occurred in the sedimentary pile with the formation of pre-consolidation breccias and folds. A period of non-deposition, or deposition and erosion, ensued with minor tectonic activity.

Sedimentation again occurred during the Cambrian with the deposition of poorly sorted muds, silts and sands on a sinking sea floor. These sediments were in part derived from local uprisen areas of Precambrian rocks, as indicated by the common occurrence of detrital strained quartz grains, and from volcanic activity contemporaneous with deposition. Volcanic activity resulted in the formation of tuffs, volcanic breccias and spilitic rocks with associated near-surface basic intrusions. The origin of the albite in the lavas is controversial but it is thought to be primary or deuteric. The final phase of the Cambrian igneous activity resulted in the intrusion of transgressive tabular sheets of ultrabasic and basic rocks.

The depositional and tectonic history of the Ordovician and Silurian periods cannot be determined in this area. It is probable from the occurrence of widespread marine sedimentary sequences of both ages in adjacent areas that they were also deposited near Waratah and have been subsequently eroded.

A major orogenic period, the Tabberabberan Orogeny, disrupted sedimentation in the Devonian. Evidence from Eugenana and Point Hibbs indicates that the tectonic movements associated with this period took place between the early Lower Devonian and the late Middle Devonian (Burns and Banks in Solomon, 1962). The first stage of tectonic activity was characterised by arcuate, long wavelength NNE-trending folds formed throughout the NW sector of Tasmania, paralleling the NNE margin of the Tyennan Geanticline.

A local stress pattern, probably in part controlled by pre-existing features, caused the development of E and NE folding in the Waratah area, the major structural feature produced being the E-trending Bischoff Anticlinorium. The intrusion of granitic batholiths, commonly into structural highs, followed folding. A local narrow cupola of a granitic batholith intruded the crest of the Bischoff Anticlinorium at Mt. Bischoff, producing radial dilation in the roof sediments, with the formation of radial fractures. These were filled by quartz-feldspar porphyry bodies injected upwards from the narrow cupola. Pneumatolytic vapours produced intense greisenization of the porphyries with the formation of topaz, tourmaline, muscovite and cassiterite. Hydrothermal solutions rose upwards along the dykes introducing iron, tin, fluorine and sulphur with the formation of pyrite, pyrrhotite, cassiterite and fluorite in the porphyries. During the hydrothermal stage of mineralization selective replacement of the dolomite by iron sulphides, cassiterite, quartz, talc and carbonate occurred. Tensional faulting occurred throughout the area forming sub-parallel sets of mainly NNW-trending faults and joints. These provided the main structural control for subsequent mineralization with the formation of tin-bearing veins over the cupola at Mt. Bischoff and silver-lead-zinc veins over the remainder of the area.

Uplift associated with the Tabberabberan Orogeny apparently initiated a prolonged period of erosion as no further deposition occurred until the late Carboniferous or early Permian. Permian boulders in the Tertiary terrestrial sediments and the occurrence of a Permian tillite in the Hellyer Gorge to the north indicate deposition of Permian sediments although none outcrop in the area. There is no evidence of Triassic deposition in the area and it is probable that an extended period of erosion occurred in the Mesozoic with the exception of small intrusions of dolerite during the Lower Jurassic (?).

Peneplanation of the area during the early Tertiary resulted in the development of an extensive gently sloping plain with rare monadnocks, one of which was Mt. Bischoff. The plain was partly covered by terrestrial sediments during the late Tertiary, with subsequent outpouring of basaltic lava which reached a thickness of about 100 feet. Rapid dissection of this plateau followed and may have been initiated by faulting and uplift. Several of the mineralized areas were exposed during Tertiary erosion resulting in the formation of gossans and residual eluvial and alluvial deposits of cassiterite at Mt. Bischoff.

Recent sedimentation has occurred in the major rivers of the area, tin-bearing alluvium and gravels being deposited in the more mature sections of their course.

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Plate I—

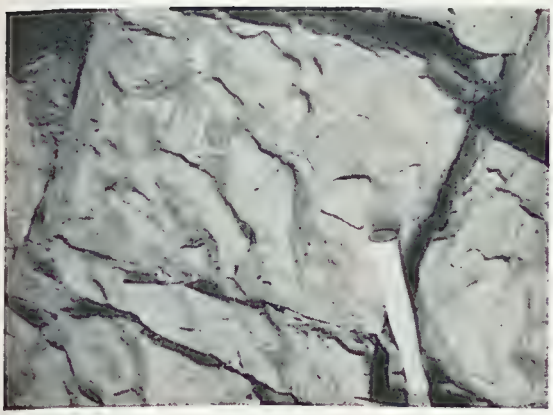

Fig. 1.—Slightly deformed flow casts in Precambrian quartzite, Waratah River.

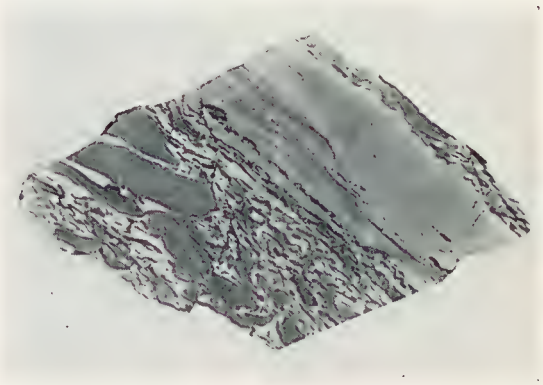

Fig. 2.—Pre-consolidated breccia in Bischoff quartzites and slates, West Mt. Bischoff. 1/16 natural size.

Fig. 3.—Tertiary sediments showing differential compaction (?) against quartz porphyry bedrock, Don Hill, Mt. Bischoff. Plate by courtesy of J. Wilson.

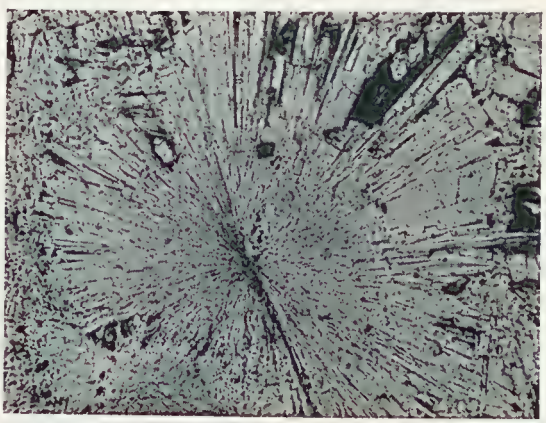

Fig. 4.—Radiating topaz replacing quartz porphyry, White Face, Mt. Bischoff; x 35.

Plate II—

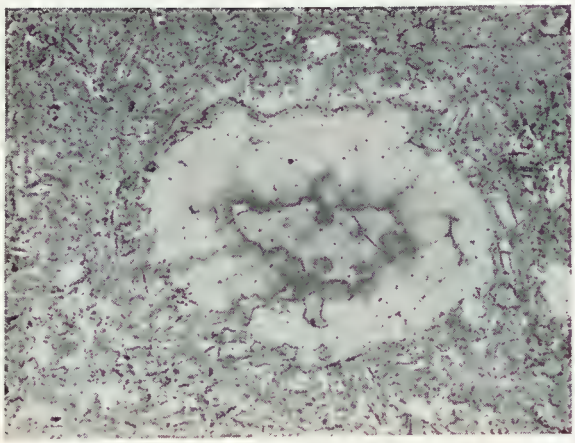

Fig. 1.—Amygdule containing quartz spherulites in Cambrian lava, Arthur River; polarised light, x 68.

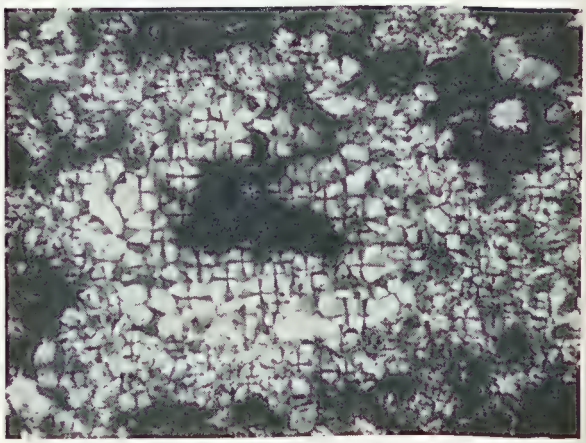

Fig. 2.—Identical field of view, crossed nicols, x 68.

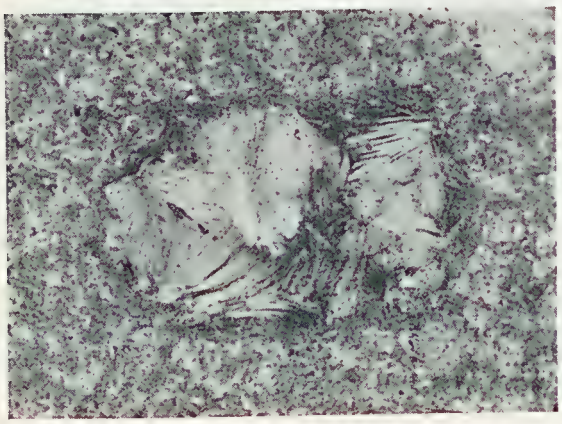

Fig. 3.—Radiating topaz pseudomorphing feldspar in quartz porphyry dyke, Mt. Bischoff; x 68.

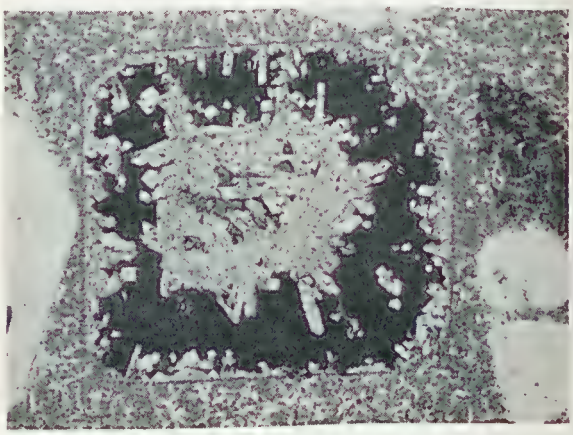

Fig. 4.—Pyrite and topaz pseudomorphing feldspar in quartz porphyry dyke, Mt. Bischoff; x 35.

PRECAMBRIAN ROCKS OF TASMANIA, PART VI, THE ZEEHAN-CORINNA AREA.

By

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(With 2 plates and 12 text figures)

ABSTRACT

Low-grade regionally metamorphosed pelites (Whyte Schist) and minor basic intrusives are overlain, probably unconformably, by unmetamorphosed sediments. These comprise the Oonah Quartzite and Slate, Interview Slate and Quartzite, Donaldson Group, Corinna Slate and the Bernafai Volcanics and are in turn overlain, probably unconformably, by the Delville Chert and Savage Dolomite. An extensive Precambrian dolerite dyke-swarm intrudes the Interview Slate. The rocks have been strongly folded and faulted, partly during Precambrian times and partly during the Tabberabberan Orogeny, and intruded by mid-Palaeozoic granitic rocks.

INTRODUCTION

The region between Zeehan, Granville Harbour, Pieman Heads and Corinna is composed of low grade metamorphic rocks and sediments which are overlain by Upper Middle Cambrian and later sediments. A combination of poor outcrop, dense vegetation and structural complexity has prevented a complete understanding of the geology of this area but the results of some reconnaissance work are presented to indicate similarities between the rocks of this area and those elsewhere in the state and to discuss some possible relationships. Emphasis is on the petrographic characteristics of the rocks.

This section of the Rock Cape Geanticline is underlain by approximately meridional belts of Precambrian sediments. A belt of metamorphosed sediments and igneous rocks (Whyte Schist) is flanked on either side by belts of unmetamorphosed sediments whose relationships to each other are not clear. As the Whyte Schist is included in the Older Precambrian of Spry (1962a) and the sediments in the Younger Precambrian, this is the first area studied in which these two groups are contiguous over an appreciable area.

OLDER PRECAMBRIAN

Whyte Schist

The Whyte Schist is an undifferentiated formation of low grade regionally metamorphosed pelite which has been intruded by a number of basic to intermediate dykes. Twelvetrees (1903) first recorded the presence of these rocks and they were briefly described by Spry and Ford (1957, pp. 2 and 4). The Whyte Schist is comparatively uniform in lithology; the main variation being in the proportion of quartzite which only seems to occur along the Pieman River south of Stringer Creek and on the coast north of Duck Creek. The degree of alteration is higher in the northern than in the southern part of the belt and the main rock-types are foliated siltstone, phyllite, mica schist and quartzite.

The tectonic terminology used here follows Spry (1963a and b); S_0 is bedding, S_1 is the foliation produced during F_1 and L_1 is the first lineation; S_2 is the second foliation formed during F_2, &c.

The foliated siltstones are light grey, glossy, rather massive rocks with a weak foliation. In thin section (e.g., No. 8131*) they show what is probably original clastic texture and consist of abundant small (0.2 mm.) quartz grains in a fine-grained matrix composed of quartz (.01 mm.) and muscovite. The larger quartz grains are ragged and lenticular in shape and show undulose extinction; the smaller quartz crystals are elongate parallel to the foliation and have blurred margins. Chlorite, zircon, rutile, magnetite, tourmaline, a carbonate and rare albite are accessories. A chemical analysis, (table I) indicates that the rock was a siliceous siltstone. It is rich in silica (80%); about 15% of muscovite is accounted for by moderate potash and alumina. Lime and magnesia are probably present as accessory dolomite.

In No. 8137 the single dominant foliation (S_1) is formed by a series of very closely spaced surfaces (.05 mm. apart) which intersect and intertwine. In No. 8147 this kind of foliation intersects compositional banding (S_0) at a low angle. No. 8128 is more complex; the foliation is of the type described above but the larger quartz grains are lenticular and oriented parallel to the foliation; small micas also have a distinct preferred orientation in this direction. There is no sign of original bedding and the foliation is taken to be S_1; it is crenulated and an irregular fracture cleavage has developed along some of the folds.

* Numbers refer to the catalogue in the Geology Department, University of Tasmania.

Specimens of argillaceous quartzite from the Pieman River south of Stringer Creek are very similar to the foliated siltstones but are coarser and richer in quartz. No. 9276 is a light grey, laminated rock with slightly crenulated bedding planes which are lustrous due to fine muscovite. In thin-section it consists of large (0.4 mm.) quartz grains (25%) in a matrix consisting of quartz (0.02 mm. diameter) and a little muscovite. The mica occurs mostly in irregular layers about 0.04 mm. thick.

The foliated siltstones become glossy and grade into phyllites with increased development of the foliation; (e.g. Nos. 9268 and 9306 from near Stringer Creek). Light grey, laminated, glossy, fine-grained crenulated phyllites are abundant in the southern part of the Whyte Schist belt and are typified by Nos. 8130, 8133, 8138, 8145, 9268, 9272, 9303 and 9318 from the Pieman River (a mile or so north and south of the Stringer Creek junction). They consist of quartz and muscovite with lesser chlorite and accessory zircon, tourmaline and rutile. A chemical analysis, table I, indicates that the phyllites were originally clay-rich siltstones. Alumina is high (18%) as is potash; the lack of lime appears to be typical of the metamorphosed pelites in the Tasmanian Precambrian.

The more-typical phyllites show a variety of textures, some of them very complex. Specimens such as 9272 from Stringer Creek appear to be comparatively simple with a single major foliation formed by alternate layers richer in quartz or in muscovite (and chlorite). This banding is visible in outcrop where it might be mistaken for bedding, but under the microscope tiny cores of an older S-surface, outlined by muscovite, can be found within the mica layers. The core of one fold is preserved as a helicitic structure within one of the sparse post-tectonic albite crystals. By analogy with the work of Spry (1962a, 1963a, 1963b) this suggests that an older foliation (S_1) has been folded and almost obliterated during the development of a younger foliation S_2. The major foliation (S_2) has been tightly folded into zig-zag crenulations and a weak fracture cleavage S_3 occurs along some axial surfaces. S_1 is also preserved as S_I in albite crystals in No. 8138.

Specimens 8130, 8133 and 8145 are macroscopically laminated phyllites with crenulated laminations. In thin-section the laminations are seen to be irregular lenses and layers alternately rich in quartz or in muscovite with quartz strongly elongate parallel to this foliation.

No. 8147 from Stringer Creek is a dark grey, fine-grained, laminated rock. In thin-section it consists of finely-grained quartz and sericite with the dominant foliation formed by closely spaced bands of parallel mica flakes. This foliation resembles bedding in hand specimen but is actually the second of two foliations. What is probably bedding is shown by broad bands alternately richer in quartz and mica; it has been isoclinally folded and fold-remnants occur within the layers of S_2. Curved trains of parallel mica flakes mark a foliation S_1 obliquely across the limbs and crests of these folds. Within the more-pelitic parts, mica flakes oblique to S_0 and S_2 outline small folds between thin layers outlining S_2. These probably represent folded remants of S_1.

The rocks to the north of Stringer Creek are schists. They are more coarsely grained, richer in mica, glossier and more strongly foliated than the phyllites. No original clastic textures have been preserved and the minerals present are quartz, muscovite, chlorite and albite with accessory magnetite, rutile, sphene and tourmaline. Representative examples are 5794, 8129, 9340, 9342, 9355, 9371 and 9380. Specimens No. 8129 and 9342 are gradational into the phyllites.

Schists from near the intersection of the Pieman River and Nancy Creek (Nos. 9340 and 9380) are lustrous, contorted grey schists with tiny white spots and consist almost entirely of small parallel muscovite flakes with about 15% of quartz as lenticular crystals (0.03 mm.) parallel to the foliation. Albite prophyroblasts up to 0.5 mm. across occur sporadically; sphene and iron-ore are abundant accessories. There is no trace of bedding (S_0) and all surfaces appear to be tectonic. The albite contains inclusions of quartz, sphene and iron-ore tracing out a curved helicitic structure discordant with the foliation of the enclosing matrix; the albite shows "pressure fringes". The albite (and is enclosed S_I) is older than the last stage of the major foliation (S_2) but it is not clear whether it is early syntectonic to the major foliation or whether the S_1 represents an older foliation to which the albite is posttectonic. The major foliation (S_2) has been crumpled and the mica flakes and iron-ore rods or flakes, which are syntectonic to S_1, have been bent around the hinges of chevron folds of S_2. This crenulation produces an irregular macroscopic lineation and a fracture cleavage S_3.

No. 8138 from Stringer Creek is a glossy light grey schist; banding (possibly bedding) parallel to the foliation has been contorted into chevron folds. The rock is finely grained and consists of alternate bands richer in muscovite and chlorite or in quartz. Tourmaline, zircon and iron-ore are accessories. Albite is also present as syntectonic crystals showing S-trends whose sense of rotation is opposite to that of the chevron folds; the latter were formed at a late stage because the mica flakes are bent around the crests. The abundant quartz is elongate parallel to the foliation but has somewhat shattered margins, probably attributable to movements associated with the chevron folding.

Albite is abundant in the schist No. 8133 from Stringer Creek. It forms round crystals with fairly straight S_I discordant to the crenulations of S_1 around them. They would appear to be posttectonic to S_1 but formed before S_2.

Amphibolites and Greenschists

Seven dykes of altered igneous rock (fig. 3) have so far been found cutting the Whyte Schist but it is probable that more occur. They are mostly basic but some are intermediate.

The foliation of the Whyte Schist curves around in an arc but the dykes are comparatively straight and trend in a north-easterly direction; in places they are parallel to the foliation and in others discordant. The igneous rocks have been metamorphosed and contain a mineral assemblage (albite, epidote, actinolite or glaucophane, chlorite,

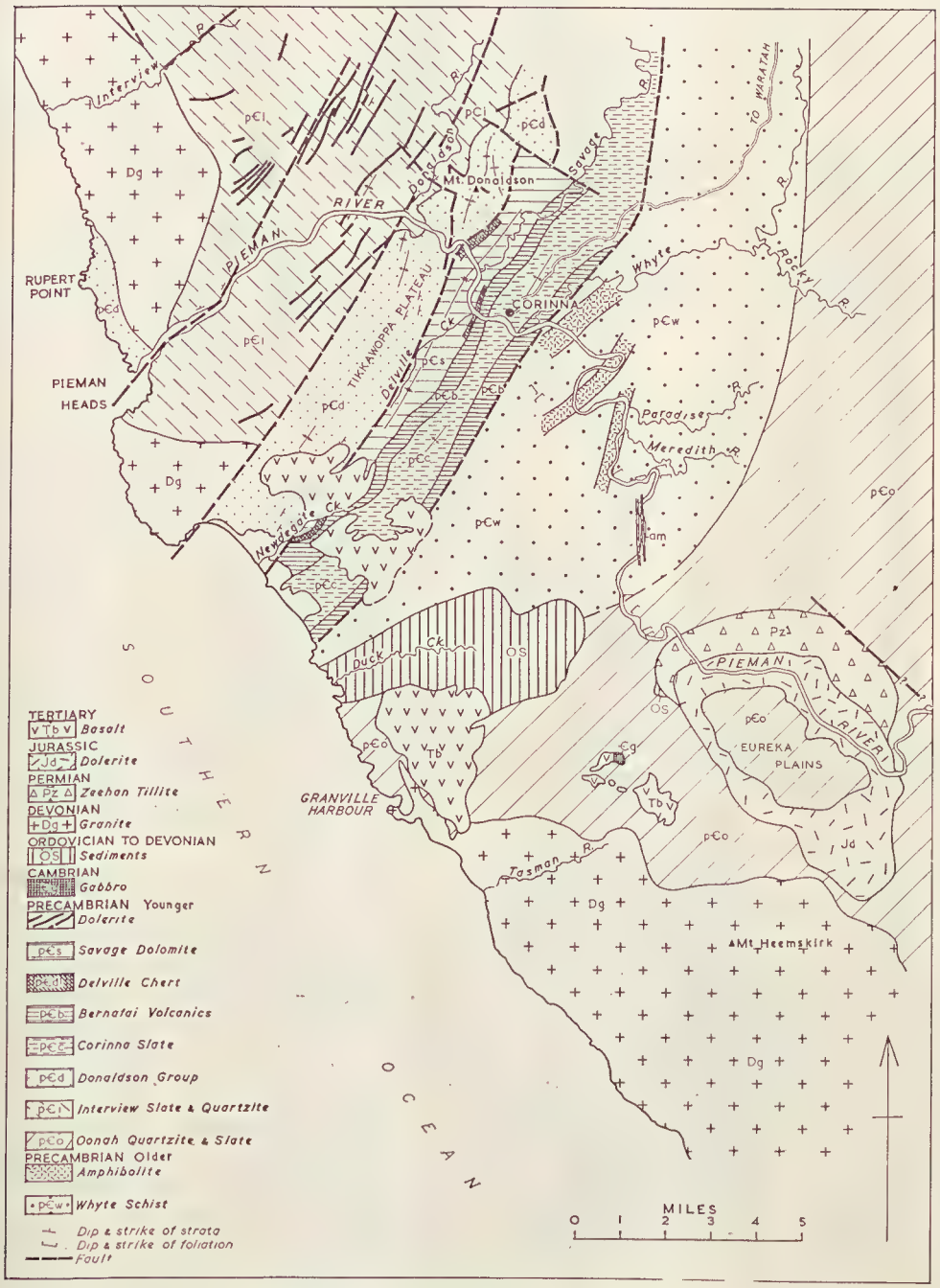


FIG. 1.—Geology of the Zeehan-Corinna Area. (Plate by courtesy of the Geological Society of Australia.)

quartz, calcite, and magnetite) which is compatible with that in the surrounding sediments. However the igneous rocks do not appear to have been as strongly deformed as the sediments. It is possible that part of the metamorphism of the Whyte Schist took place before the igneous injection and part afterwards i.e. the intrusions may have taken place between F_1 and F_2.

The original textures of the igneous rocks have been destroyed. During the metamorphism, sheared zones developed either along the margins of the dykes or within them and a weak foliation was formed, generally at an angle to the dyke margin. Microscope slides show that there is very little difference between amphibolites and greenschists; the greenschists appear to more finely grained and more strongly foliated than the amphibolites and some are banded.

TABLE I

	(1)	(2)	(3)	(4)	(5)
SiO_2	63.38	80.14	62.64	49.20	48.38
Al_2O_3	17.84	6.18	13.87	13.59	11.52
Fe_2O_3	1.68	1.21	1.18	2.78	7.05
FeO	3.05	2.05	3.17	10.98	7.15
MgO	3.49	2.25	6.33	6.66	7.11
CaO	tr	1.64	6.16	8.13	7.10
Na_2O	0.48	0.37	4.99	3.18	4.43
K_2O	4.31	1.45	0.93	0.08	0.30
H_2O+	4.61	3.47	1.12	3.28	2.50
H_2O-	0.13	0.17	nil	0.05	0.06
MnO	tr	0.05	0.11	0.21	0.22
TiO_2	0.85	0.47	0.10	1.63	2.02
P_2O_5	0.12	0.12	nil	0.21	0.12
	99.94	99.57	100.60	99.97	99.96

(1) Phyllite, Whyte Schist, No. 8147, Pieman River.
(2) Schistose siltstone, Whyte Schist, No. 8131, Pieman River.
(3) Amphibolite, Rocky and Whyte Rivers.
(4) Amphibolite, Stringer Creek, No. 8121.
(5) Glaucophane amphibolite, Pieman River, No. 9281.
Analyst: Tas. Dept. Mines.

The specimens from the big bend in the Pieman near Nancy Creek are rather finely grained, irregularly schistose rocks consisting of two forms of amphibole, albite, biotite, chlorite, epidote, and accessory quartz, sphene and magnetite. The foliation is outlined by parallel lenses of sphene aggregates up to 5 mm. long, sub-parallel laths and needles of amphibole, and lenses rich in albite or quartz (fig. 2e). The amphibole occurs as large, ragged crystals of very pale actinolite (averaging 0.3 mm. across) which has partly broken down into tiny laths or needles (about 0.1 mm. long) of medium green or colourless amphibole. Green isotropic chlorite forms irregular masses; albite occurs as fresh, untwinned crystals in irregular aggregates or more typically as round crystals (0.1 mm. in diameter) containing needles of actinolite. Epidote (0.03 mm. to 1mm.) is present and quartz occurs as lenticular aggregates or as thin veins. Twisted, partially chloritized brown biotite is abundant as tiny parallel or randomly disposed flakes.

The coarse amphibole is probably related to an early crystallization stage to which biotite probably formed posttectonically. The small amphiboles are syntectonic to a second stage (as in also the chlorite and some quartz), the albite is posttectonic, the relations of the epidote are not clear but it appears to have crystallized at each stage.

Specimens 8121, 9277, 9273 from near Stringer Creek are massive and green. In thin-section they have an irregularly banded texture and consist of albite and actinolite with epidote, zoisite, chlorite and leucoxene. The actinolite occurs as felted fibres and laths and is pleochroic from bluish green to green. The analysis in table I corresponds to an olivine basalt with high soda.

No. 9277 from Stringer Creek is much coarser. The large (up to 3 mm.) aggregates of sphene granules have a grid shape which is probably relict after the form of original ilmenite. Albite occurs as large aggregates of interlocking crystals each of which tend to have a round shape (fig. 2f). A few small flakes of muscovite are present.

Some of the less common varieties include No. 9281 which is a bluish rock south of the Stringer Creek-Pieman River junction. It is weakly foliated and consists of 60% glaucophane (crossite, pleochroic with Z=pale yellow, Y and Z=blue, uniaxial negative with strong dispersion) as laths about 2 mm. across. Epidote is abundant (25%) in grains 0.05 mm. across or as 0.5 mm. aggregates. There is 15% of albite and accessory sphene, apatite, magnetite, muscovite, tourmaline and chlorite. The rock is veined with yellow epidote and a little brown hornblende. The analysis in table I indicates that the rock was originally basic and is soda-rich.

No. 9366 from the body at the mouth of the Meredith River is typical of the banded varieties of greenschist. It is a fine-grained, greenish-grey, platy and banded rock. Under the microscope it is seen to consist of coarse bands containing round albite and ragged actinolite with sphene and chloritized biotite, and fine bands composed of albite, zoisite and a little bright green chlorite, chloritized biotite and needles of almost colourless actinolite. It is probable that the banding is due to the metamorphic differentiation of an original uniform igneous rock.

A layer of greenschist cuts the Pieman River about a quarter of a mile upstream from the mouth of the Whyte and causes a constriction of the river. No. 9378 from here is a light greenish grey rock with a weak cleavage, containing elongate, light coloured flakes about ½ mm. across. Under the microscope it is finely grained and weakly foliated and consists of albite, epidote, actinolite, chlorite and sphene. The actinolite is pale green; the chlorite is pale green with anomalous interference colours; the epidote is zoned with yellow cores and colourless rims. The albite occurs as finely-grained aggregates generally with irregular lenticular form; some of the aggregates have a rectangular shape suggestive of original phenocrysts.

A few feldspar-rich meta-igneous rocks have been found and one was described by Spry and Ford (1957) from near the junction of the Whyte and the Rocky Rivers. The analysis in Table I shows that it is intermediate and sodic. No. 8122 appears to form part of the amphibolite mass at the Stringer Creek junction and outcrops on the western bank. Its macroscopic appearance is that of a fine-grained, rather shattered quartzite but in thin section it is seen to consist entirely of albite.

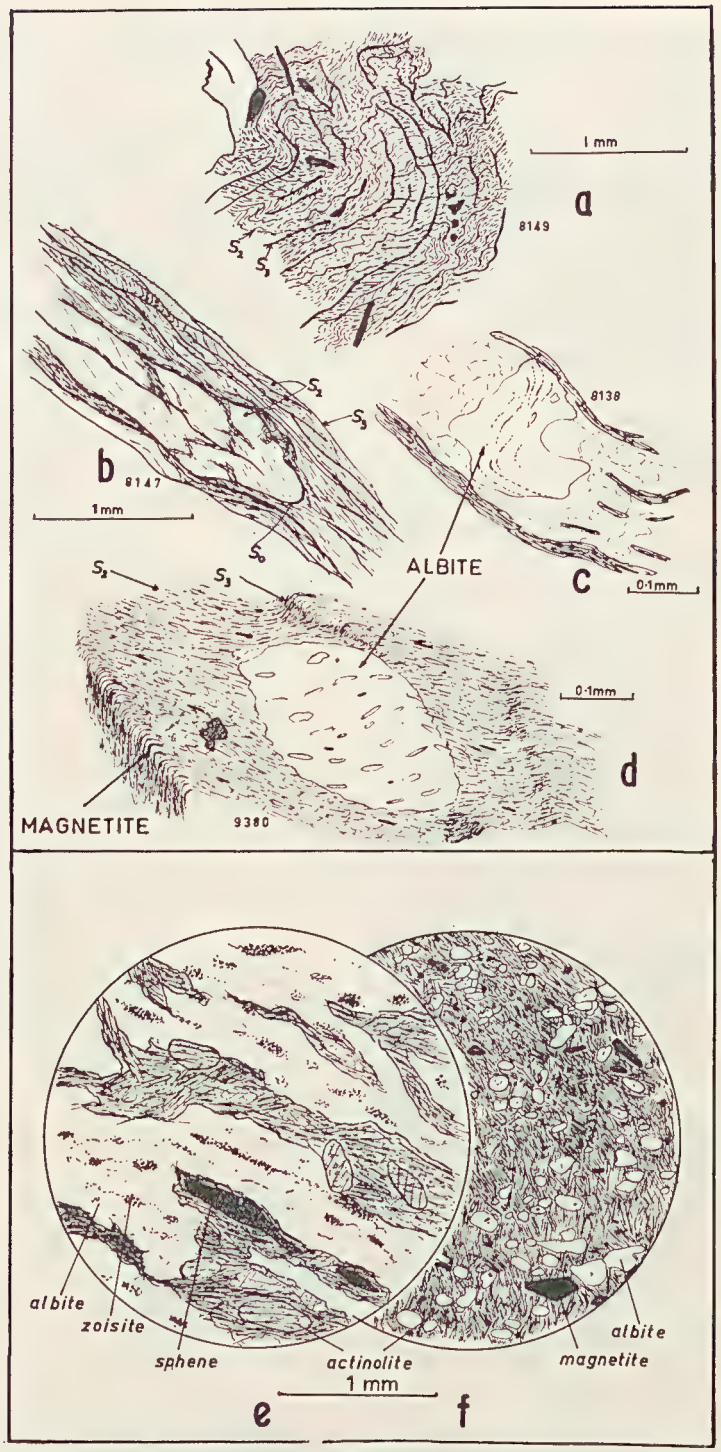
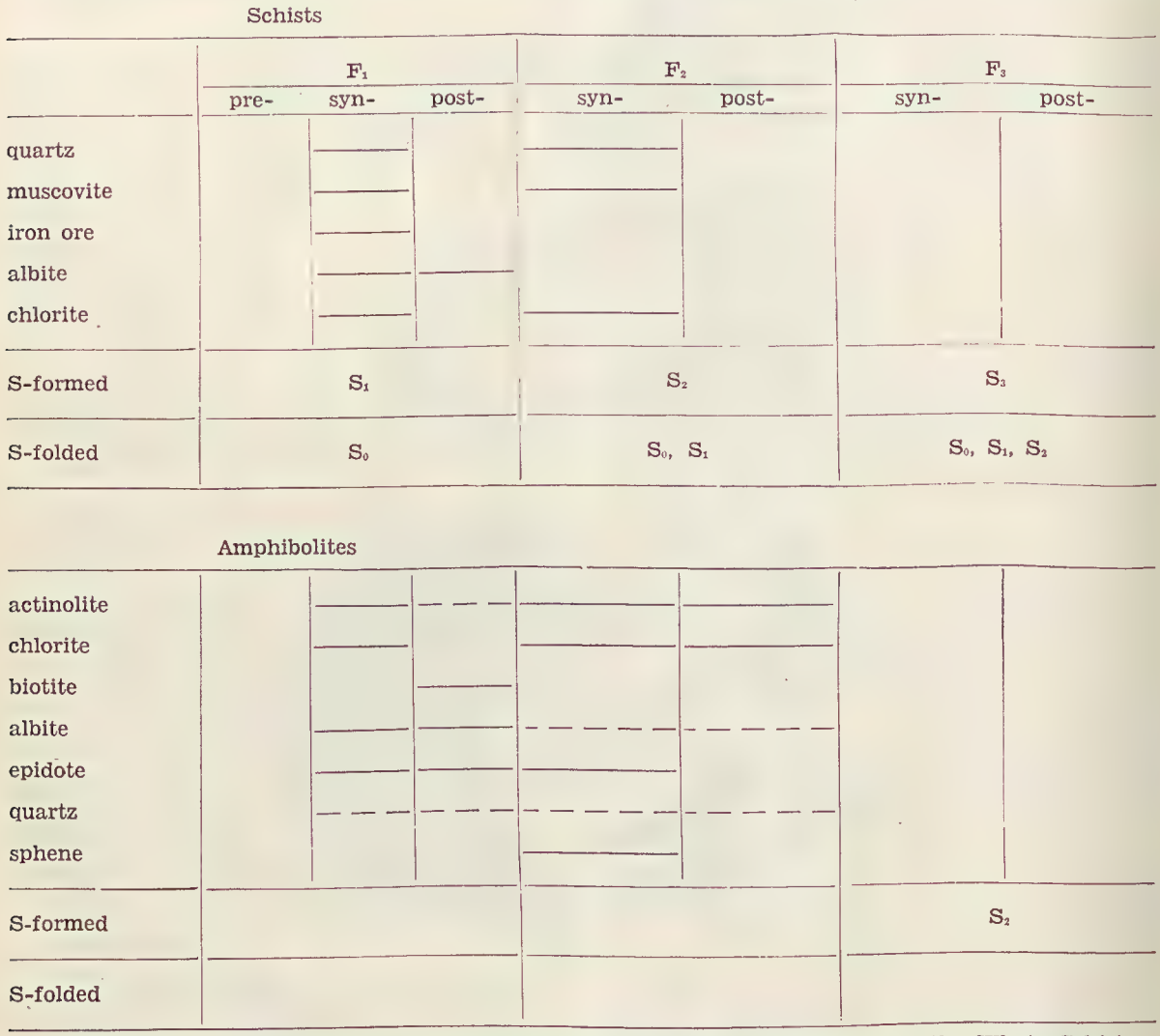


FIG. 2.—Textures of some varieties of Whyte Schist. (*a*) S_2 and S_3, in phyllite. (*b*) Three foliations, possibly S_0, S_2 and S_3, in phyllite. (*c*) and (*d*) Helicitic structure in posttectonic albite. (*e*) Foliated amphibolite. (*f*) Posttectonic albite and magnetite in amphibolite.

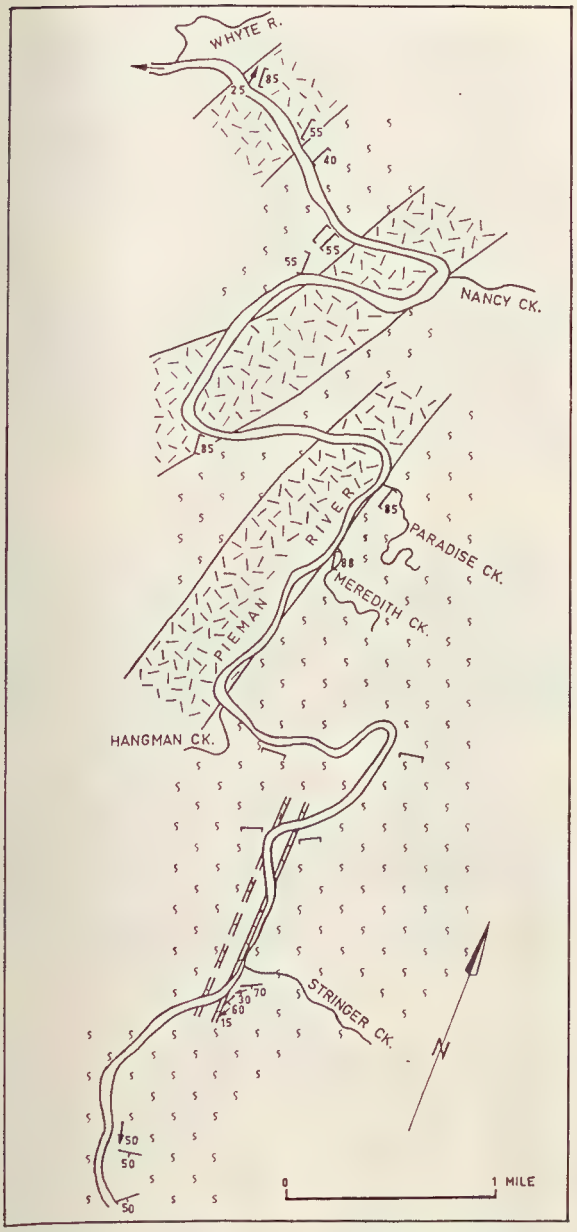
Specimen No. 9406 outcrops on the southern bank of the Pieman River, 1½ miles upstream from the Nancy junction. In hand specimen it is a light coloured, spotted, rather massive rock; it does not closely resemble either a sedimentary schist nor an amphibolite. In thin section it is fine to medium-grained and very irregularly textured; it is not particularly schistose and consists of undulose quartz, green chlorite, albite and a little epidote, magnetite and muscovite. The aggregates of albite and of quartz appear to have been large crystals which have ben crushed. Some of the albite crystals contain S_i at an angle to the chlorite flakes wrapping around them. Nothing is known of the field relations of this rock but it is tentatively regarded as an acid to intermediate representative of the amphibolites.

The amphibolites and related types have been derived from a group of basic (with some intermediate and perhaps acid varieties) igneous rocks by a process involving some shearing at rather low temperatures. The rocks belong to the albite-muscovite-chlorite subfacies of the Greenschist Facies, as do the enclosing sediments. In the absence of evidence suggesting soda metasomatism, the significant soda-content is tentatively regarded as an original characteristic of the igneous rocks.

The presence of only one clearly recognizable foliation in the amphibolites (although there appear to have been two stages in the metamorphism) as contrasted to a possible three foliations in the sediments prevents close correlation of their metamorphic history and suggests that perhaps the igneous rocks might have been intruded after F_1.



Chronology of crystallization and deformation of schists and amphibolites in the Whyte Schist.



GEOLOGICAL SKETCH MAP OF PIEMAN RIVER IN THE WHYTE RIVER–STRINGER CREEK SECTION

FIG. 3.—Amphibolite dykes within Whyte Schist along the Pieman River.

YOUNGER PRECAMBRIAN

The stratigraphic succession is not clear partly because of poor outcrop and thick vegetation and partly because the major structure is not well understood. The rocks to the east of the Whyte Schist structural high differ from those to the west. The Oonah Quartzite and Slate occurs to the east of the Whyte Schist and may be the oldest of the younger Precambrian sediments. To the west are the Interview Slate and Quartzite, the Donaldson Group, the Bernafai Volcanics, the Corinna Slate, the Delville Chert and the Savage Dolomite. The probable succession is as follows:

Top
- Savage Dolomite
- Delville Chert
- Unconformity?
- Bernafai Volcanics
- Corinna Slate
- Donaldson Group
- Interview Slate and Quartzite
- Oonah Quartzite and Slate
- Unconformity

Oonah Quartzite and Slate

A great thickness of white quartzites and grey slates extends from the coast at Granville Harbour, south-east to Zeehan, and north-east across the Eureka Plains to the open country north of the Pieman. The sediments were described briefly by Twelvetrees and Ward (1910) and by Waterhouse (1915); they were named the Oonah Quartzite by Hills and Carey (1949) and the formation was formally defined as the Oonah Quartzite and Slate by Spry (1958). The "Corinna Beds" of Spry and Ford (1957) included part of this formation.

No attempt has been made to subdivide the formation because outcrop is very poor across the mature Henty Surface and no undisturbed stratigraphic succession has been found. The dominant rock is a white, flaggy quartzite with abundant clastic muscovite along the bedding. The slates are grey glossy rocks with a strong cleavage. A fine lineation due to crenulation of the cleavage is present in many specimens. The thickness of this formation cannot be given as the structure is not known in detail and the top is not visible. The sediments are tightly folded on a small scale and also form a large syncline. The area of outcrop is over 200 sq. miles and it does not seem likely that less than 5 or 10,000 of sediments could be present. The formation appears to overlie the Whyte Schist unconformably (this relation is discussed in detail later) and is overlain unconformably by the Owen Conglomerate at Duck Creek and the Cambrian Dundas Group at Zeehan.

Campana and King (1963, p. 14) consider that the Oonah Quartzite and associated slates—

(1) overlie "stressed slates and quartzites of the Davey Group with apparent unconformity" at Oonah Hill,
(2) include the Montana Volcanics,
(3) are probably early Cambrian in age.

There is no evidence to support these conclusions and such statements only confuse the situation. Detailed mapping in the Oonah Hill region does not reveal rocks which might reasonably be correlated with the Davey Group, nor does it suggest

an unconformity beneath the Oonah Quartzite. The discovery of volcanics in sediments related to the Oonah (pp. 16, 17 of this paper) makes it important to clarify the position of the igneous rocks in the Queen Hill-Oonah Hill area. Although the structure just north-west of Zeehan is complex, it seems very probable that the Montana Volcanics are continuous with fossiliferous Cambrian sediments and that there is an unconformity between the Oonah and the Cambrian. The igneous rocks found within the Oonah Quartzite near Zeehan are discordant and thus are intrusives; they may have acted as feeders to the Cambrian volcanics. They resemble basic igneous rocks belonging to the Dundas Group elsewhere but do not resemble the Bernafai Volcanics. The evidence given later in this paper and by Spry (1962a) is strongly against a Cambrian age for the Oonah Quartzite and related sediments and Campana and King's (1963, p. 14) acceptance of a Cambrian age appears to be based only on the fact that "they are succeeded by fossiliferous beds of Upper Middle Cambrian age".

The quartzites consist of angular to well-rounded grains of quartz with a little weathered feldspar, clay fragments and clastic muscovite in a matrix of fine sericite and chlorite. The matrix of the sandstones has not been appreciably recrystallized and most rocks contain no cleavage; the bedding-plane fissility is due to clastic muscovite flakes.

Chemical analyses of two specimens (Table II) from Oonah Hill, just north of Zeehan, indicate that the rocks are siliceous with an argillaceous impurity. Lime is deficient, potash exceeds soda, and the iron is moderately oxidized. The rocks do not have sufficient labiles to be named graywackes but resemble some quartzose subgreywackes (Pettijohn, 1957, p. 316).

The quartzite from Oonah Hill is light grey and well-bedded with abundant mica along the bedding and many irregular quartz veins. In thin section the rock is composed of small quartz grains (generally not much more than 1/16 mm. in diameter) in a fine matrix of sericite and clay (?) (plate II, No. 1). The quartz grains were originally well-rounded but now have an angular form due to secondary enlargement by authigenic quartz. The large, bent and ragged muscovite and chloritized biotite flakes are clastic. A few grains of a fine-grained aggregate of sericite are probably weathered feldspar.

The quartz in many specimens (e.g. 8022) has been derived from a terrain containing dynamically altered rocks; the quartz grains are elongate and show undulose extinction and deformation lamellae. In many rocks these strained quartz grains are surrounded by a fine sericitic matrix which shows no cleavage or by an unstrained quartz cement; the quartz grains are assumed to have been strained prior to their incorporation into the sediment.

Many sandstones (e.g. 8023) contain chlorite as flakes and sheafs; 8016 contains chert fragments; 8025 is coarse with grains of chert, quartzite and slate. (Plate II, No. 1.)

The pelites interbedded with the quartzites were originally mainly siltstones. No. 8022 is light grey and foliated; microscopically it consists of small quartz grains and large flakes of clastic muscovite and biotite in a sericite-rich matrix. No. 8029 is a non-foliated variety and consists of very fine quartz and sericite with accessory chlorite, zircon, rutile and idomorphic tourmaline.

Sediments West of the Whyte Schist

The sediments in the vicinity of Corinna, between the Whyte River and the sea, are similar to the Oonah Quartzite and Slate in their degree of metamorphism but differ in lithology. The Donaldson Group, Interview Slate and Quartzite, &c., are considered to overlie the Whyte Schist unconformably (as does the Oonah Quartzite) but the stratigraphic relations between the unmetamorphosed sediments to the east and to the west of the Whyte Schist belt are not known.

The Interview Slate and Quartzite underlies the Donaldson Group but the Savage, Delville, Bernafai and Corinna rocks are separated from the Interview and Donaldson by a fault. Steep dips, lack of facings and poor outcrop have so far prevented determination of the structure involving the Savage, Delville, Bernafai and Corinna and although their stratigraphic relations are not certain the following succession is favoured.

Top	Savage Dolomite
	Delville Chert
	Unconformity?
	Bernafai Volcanics
	Corinna Slate
	Donaldson Group
Bottom	Interview Slate

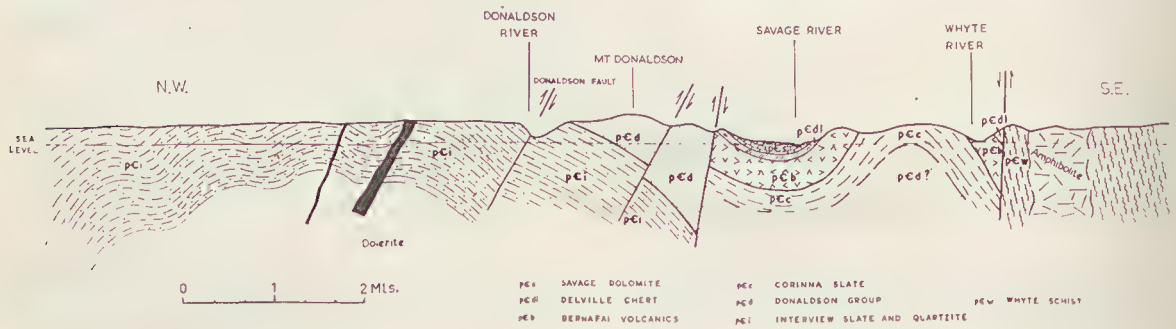


FIG. 4.—Cross section through the Corinna area.

Interview Slate and Quartzite

The argillites occupying a belt of country parallel to the coast between the Donaldson River and the long granite mass north of Pieman Heads were referred to as the "Interview Beds" by Spry and Ford (1957, p. 2) but the formation is now formally defined as the Interview Slate and Quartzite. It underlies the Donaldson Group conformably but the lower limit is not exposed, the beds forming a broad anticline. The thickness is not known exactly as the sediments are repeatedly folded into asymmetrical folds a few tens of feet across but it does not seem likely that the total thickness could be less than 5000'. The type locality is the section along the south bank of the Pieman River from just east of the Donaldson River to the coast. It is possible that this formation is equivalent to the Balfour Slates and Sandstones of Ward (1911) but the area between the Interview Plains and Balfour has not yet been mapped. Slumps, mudflakes (specimens 5771, 5765) and cross bedding are abundant. Most specimens possess a cleavage oblique to the bedding and parallel to the axial surface of visible minor folds.

The argillites (e.g. No. 9389) are light, cream-coloured slates with slightly wavy bedding planes 1 mm. to 1 cm. apart and a weak oblique cleavage. Microscopically, the finer layers contain very small sericite flakes with quartz and very little chlorite; the coarser layers consist of quarts (average 0.03 mm. diameter) and flakes of chlorite (0.1 mm. long) with lesser sericite. Ragged laths of chlorite may have originally been biotite. Accessories are idioblastic mauve and green tourmaline, zircon, pyrite and magnetite. Some of the slates (9349, 9379, 9377) contain a little albite.

Quartzites are thin and not abundant. They are finely grained (e.g. 9351) and massive and contain approximately 85% quartz and 5% albite with the remainder sericite; accessories are chlorite, rounded zircon and rutile.

The formation has been intruded by Devonian granite near the coast and is thermally metamorphosed (Spry and Ford, 1957). An extensive dolerite dyke swarm intrdues this formation over a wide area.

Donaldson Group

At least 1870' of white quartzite with minor conglomerate and slate overlies the Interview Slate and Quartzite conformably at Mt. Donaldson where the following succession was measured:

Top	Nonesuch Slate	200'+
	Gutherie Quartzite	250'
	Longback Conglomerate	40'
	Tikkawoppa Quartzite	700'
	Gates Conglomerate	40'
	Mametz Quartzite	600'
Bottom	Montgomery Conglomerate	40'
		1,870'

The term Donaldson Beds was used by Spry and Ford (1957) but the sediments are now formally defined as a group. As the massive white quartzites are dominant and the intervening conglomerates discontinuous, it might be considered preferable to regard the beds as a **formation** rather than a **group** but this must be decided in the future after more extensive mapping.

The stratigraphic succession of formations within the Donaldson Group seems fairly clear in general although there are complexities in detail. The beds are structurally disturbed, being thrown into folds ranging from $\frac{1}{4}$ to $\frac{3}{4}$ of a mile across, with numerous faults; the more important of these structures are shown in Fig. 6. In addition the slates commonly show contortion with small crenulations several inches across. Coupled with the difficult structure is a lack of outcrop and considerable facies change.

It is difficult to decide just what should be taken as the base of the Donaldson Group, but the most significant sedimentional event was the change from the argillaceous sedimentation of the Interview slates to the arenaceous and rudaceous deposition of the Donaldson Group. The change from

Table II.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SiO_2	87.54	85.46	86.08	61.90	73.96	57.68	46.74
Al_2O_3	6.42	7.76	7.40	14.25	13.05	12.88	14.94
Fe_2O_3	0.46	0.71	0.50	1.00	0.43	3.69	2.90
FeO	0.80	0.51	0.83	3.53	2.89	6.41	10.66
MgO	0.41	0.61	0.51	6.76	1.38	5.63	7.04
CaO	Tr	Tr	0.24	4.39	0.40	4.75	9.60
Na_2O	0.05	0.18	0.18	3.44	4.26	3.04	2.77
K_2O	1.49	2.06	2.19	1.50	2.02	1.70	0.06
H_2O+	1.84	1.83	1.42	2.01	1.53	2.84	3.54
H_2O-	0.15	0.11	0.13	nil	0.17	0.36	0.14
P_2O_5	0.08	0.05	0.03	0.15	0.06	0.15	0.16
TiO_2	0.42	0.45	0.42	0.62	0.39	0.74	1.75
MnO	Tr	Tr	Tr	0.05	0.04	0.13	0.26
	99.66	99.64	100.00	99.60	100.58	100.56	99.93

(1) No. 8091, quartzite, Oonah Hill.
(2) No. 8027, quartzite, Oonah Hill.
(3) No. 7991, quartzite, Burnie Quartzite and Slate.
(4) No. 8045, hornfels, Granville Harbour.
(5) No. 7157, greywacke siltstone, Crayfish Creek.
(6) No. 9270, tuff, Bernafai Volcanics.
(7) No. 9305, altered basalt, Bernafai Volcanics.
Analyst: Tas. Dept. Mines.

the cream slates of the Interview to the black and grey slates of the Donaldson is also striking but is more gradual and dark slates occur interbedded with cream ones along the Donaldson River over a thousand feet below the base of the Donaldson Group.

The conglomerate along the Montgomery Ridge is a convenient formation to use as a base but unfortunately does not appear to occur universally and is absent on the Pieman River. The first conglomerate to appear on the Pieman River is the Gates Conglomerate which occurs just east of Hell's Gates where it is underlain by 600 ft. of Mametz Quartzite.

Montgomery Conglomerate: 0-40'

A white massive conglomerate with well-rounded quartzite pebbles in a sandy matrix outcrops on the northern slope of Montgomery Ridge conformably overlying grey siltstone, cream slate and thin quartzite of the Interview Formation.

Mametz Quartzite: 600'

The Montgomery Conglomerate is overlain by white quartzite and appears to pass laterally into the same rock along Mametz Ridge. The formation thickens to the south and forms the constriction called "Hell's Gates" on the Pieman River and underlies the greater part of the Tikkawoppa Plateau. Near the base it is platy with thin slate beds but is more massive at the top.

Specimen No. 9396 is a light grey, rather vitreous quartzite with boudinage structure from the Mametz Quartzite at Hell's Gates. In thin-section (Plate II, No. 2) it is seen to be composed of clastic quartz grains about 0.3 mm. across which are well rounded and have a high sphericity with a secondary silica cement surrounding each grain and growing in optical continuity with it. The quartz is undulose and shows "deformation lamellae" but the rock appears to be only slightly deformed. Parallel lines of tiny inclusions cut across a number of adjacent grains and possibly represent tiny fractures which have been "healed". A few whispy flakes of sericite are present.

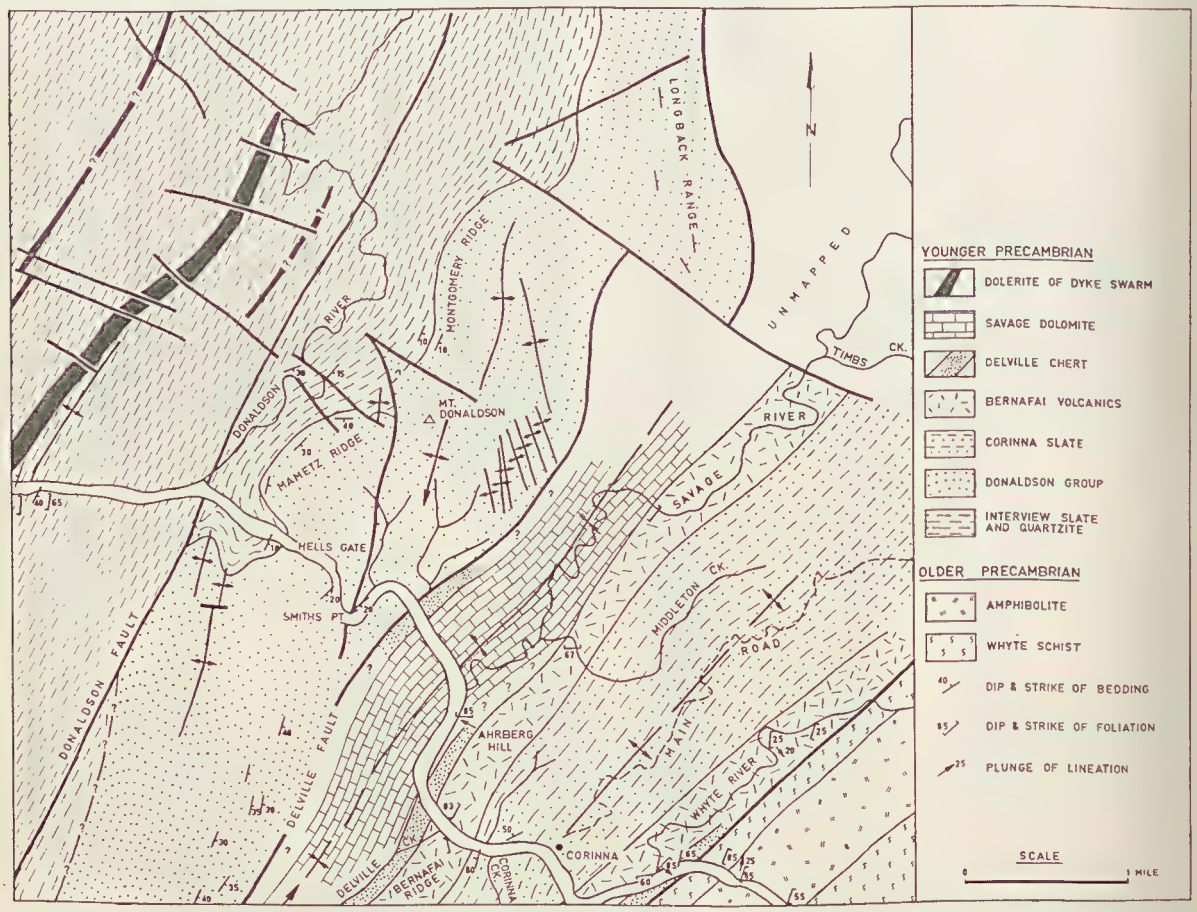


FIG. 5.—Geology of part of the lower Pieman area.

Specimen No. 9399 from Tikkawoppa Plateau, 1½ miles south of Hell's Gates is more strongly deformed. In the hand specimen it is a pure white, very fine-grained, massive quartzite. In thin section it is seen to consist of quartz grains which average 0.25 mm. in diameter set in a matrix of very tiny crystals. The large grains are undulose and contain deformation lamellae; the parallelism of the large elongate grains gives the rock a deformed appearance, and this is supported by the blurred quartz boundaries. A fabric diagram of the large grains (fig. 8a) suggests that the rock has been deformed but it is debatable whether or not a preferred orientation exists. The zero areas are small, the maxima small and low (generally 3%, one 4%), and the symmetry is triclinic.

Specimen 9372 occurs at Hell's Gates in a bed showing boudinage structure. The rock consists of ragged elongate quartz crystals in a finely granular crushed matrix of quartz. A fabric diagram of the large quartz grains (fig. 8b) shows that a preferred orientation is probably present but it is not strong and the symmetry is triclinic. There is some suggestion of two crossed girdles intersecting in a point near the axis of the boudins.

The fabric diagram (fig. 8c) of specimen 2226 (Plate II, No. 4) from the large outcrop on the beach immediately south of the mouth of Newdegate Creek is more conclusive. The rock has a mortar texture and the fabric of the large quartz grains shows a distinct preferred orientation with possibly two crossed girdles intersecting near the lineation. Fig. 9d shows the positions of the optic axes in 70 undulose quartz grains from 2226. There is a much as 30° difference in the spread of the axes within a single grain.

The diagrams are significant. The Donaldson Group is regarded as typical of the unmetamorphosed group of Precambrian rocks and in general is only slightly deformed, in fact its comparative lack of deformation allows it to be distinguished from the older Precambrian. The diagrams show that in places the younger Precambrian sediments may be quite strongly deformed whereas fabric diagrams of Fisher Group quartzite from the older Precambrian at the Mersey River show that these rocks may in places be only slightly deformed.

No. 9325 is a steel grey, fine-grained slate from this formation on the Tikkawoppa Plateau. It has a cleavage at an angle to the bedding and a fine crenulation. Microscopically it is a poorly sorted, finely grained rock composed of ragged quartz grains (average size 0.08 mm.) in a fine-grained matrix of quartz (0.02 mm.) and sericite. The sericite is directed along a large number of closely spaced surfaces which are oblique to the bedding and apparently also at right angles to the axial surfaces of small creulations of the bedding.

Gates Conglomerate 0-40'

The Mametz Quartzite is overlain by the 40 ft. thick Gates Conglomerate at the eastern part of Hell's Gates. It consists mainly of well-rounded quartzite boulders in a phyllitic matrix and is overlain by the laminated and slaty quartzites of the lower part of the Tikkawoppa Quartzite. The Conglomerate horizon can be followed up the southern side of the Pieman valley and across the Plateau for at least half a mile but its northerly extent is debatable. Despite numerous traverses up the northern face of Hell's Gates no outcrop of conglomerate was found higher than 50' above river level. Further along Mametz Ridge where the outcrop is better there is still no sign of the conglomerate so that it is assumed to pass laterally into sandstone.

The argillaceous matrix of the conglomerate is strongly foliated but the pebbles show no evidence of having been deformed.

Tikkawoppa Quartzite: 700'

The Gates Conglomerate is overlain by slaty quartzites and massive quartzites which extend from Hell's Gates for about a quarter of a mile to the east. These slaty quartzites pass into pure white quartzites along Mametz ridge and would

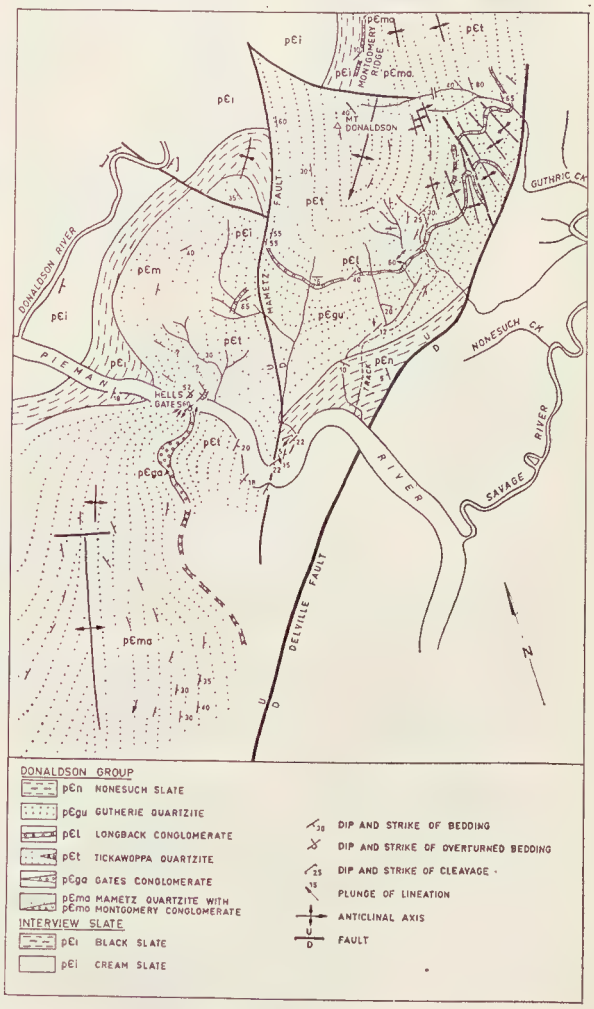


FIG. 6.—Geology of Mt. Donaldson.

appear to be equivalent to the quartzites around the peak of Mt. Donaldson. If the present stratigraphic and structural interpretation is correct, the Tikkawoppa Quartzite is bounded below by the Gates Conglomerate and above by the Longback Conglomerate. It has a total thickness of about 700 feet. It is not possible to separate the Mametz and Tikkawoppa Quartzites where the Gates Conglomerate is absent, and future mapping may show that these two formations should be combined.

No. 9295 is a light grey, coarse sandstone from the upper part of the Tikkawoppa Quartzite near Gutheries Creek. It is an evenly grained rock consisting generally of quartz grains averaging 0.5 mm. across (Plate II, No. 6). The quartz grains are undulose with deformation lamellae but are well rounded and have a quartz cement. Clastic grains of quartzite are distinguishable under the microscope. Zircon is accessory.

Specimens numbered 9405 and 9397 were collected from slaty horizons near the base of the Tikkawoppa Quartzite and are light grey, somewhat lustrous, fissile rocks. In thin section they are finely grained and consist of about 10% of quartz grains averaging 0.2 mm. in diameter in a fine-grained matrix of quartz (from 0.04 mm. downwards) and parallel sericite. They have a patchy texture due to coarser and finer-grained areas. Some clastic muscovite and chloritised biotite are present together with authigenic chlorite and accessory zircon, iron ore and rutile. Tourmaline occurs as well rounded (allothogenic) grains and idioblastic (possibly authigenic) prisms.

Longback Conglomerate: 40'

The basal formations around Mametz Ridge are separated from those of Mt. Donaldson by a fault with several hundred feet throw which disturbs the unity of the stratigraphic sequence, but a comparatively unbroken sequence outcrops from the peak down to the Pieman River to the south. The white quartzite of the mountain top is thought to be the Tikkawoppa Quartzite and this is overlain by a persistent band of conglomerate which outcrops around the southern flank of the mountain. This conglomerate is about 40 ft. thick and consist or well-rounded quartzite pebbles and boulders in a sandy or slaty matrix and is named the Longback Conglomerate.

Most of the conglomerates outcrop badly and are represented mainly by soil containing rounded pebbles and boulders. A number of conglomeratic horizons occur towards the top of the Tikkawoppa Quartzite, but the Longback Conglomerate is more continuous than the others.

Four sections (fig. 7) were measured through the Longback Conglomerate and the immediately overlying and underlying beds. The first section is across the north-eastern slopes of Mt. Donaldson, half a mile north of the Pieman; and the second, third and fourth at quarter-mile intervals to the north.

No. 9259 is a specimen of the Longback Conglomerate from a quarter of a mile north of Hell's Gates. The matrix consists of sub-angular quartz grains 1 mm. or less across, with a moderate sphericity. The grains are undulose and have lamellae but it is not clear whether they have been stressed in this rock or whether they are clastic particles derived from a metamorphic terrain. The larger quartz grains are set in a very fine-grained and undirected mass of quartz and sericite with accessory tourmaline and rutile.

Gutherie Quartzite: 200-300'?

The Longback Conglomerate is overlain by the Gutherie Quartzite which has its type locality along the track from the Pieman River to Mt. Donaldson where it first leaves the forest of the Pieman Valley and rises across the open button-grass spurs, half a mile north of the Pieman. The name was taken from Gutheries Creek which occurs half a mile north of here. It is difficult to measure the thickness but it would probably be between two and three hundred feet. Slate, pebbly slate and quartzite-conglomerate horizons occur within the quartzite.

No. 9318 from the Gutherie Quartzite is a pale grey, lustrous, slaty quartzite with bands rich in sand-grade material, fine-sand grade and silt. Slump structures are visible and a cleavage is oblique to the bedding. The coarser bands are rich in quartz and finer ones rich in sericite. The sericite is parallel to the bedding in the pelitic layers but lies obliquely to give a slaty cleavage in the more siliceous layers. Accessories are idioblastic tourmaline and well-rounded zircon.

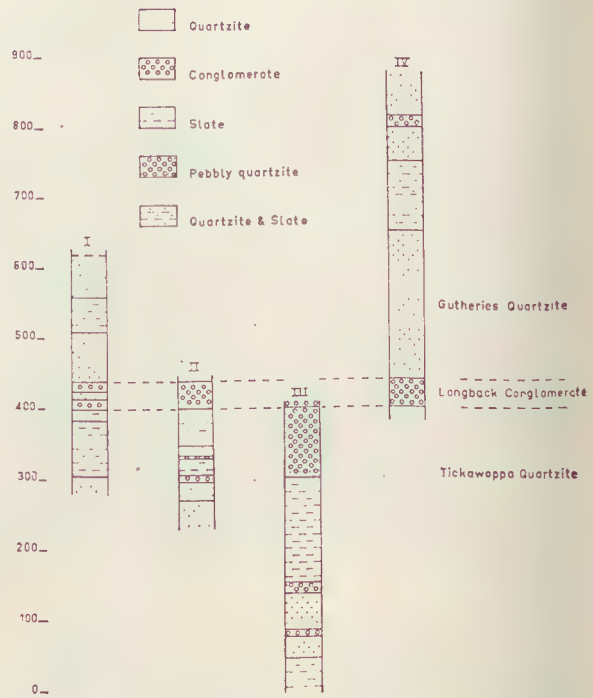


FIG. 7.—Stratigraphic sections through part of the Donaldson Group.

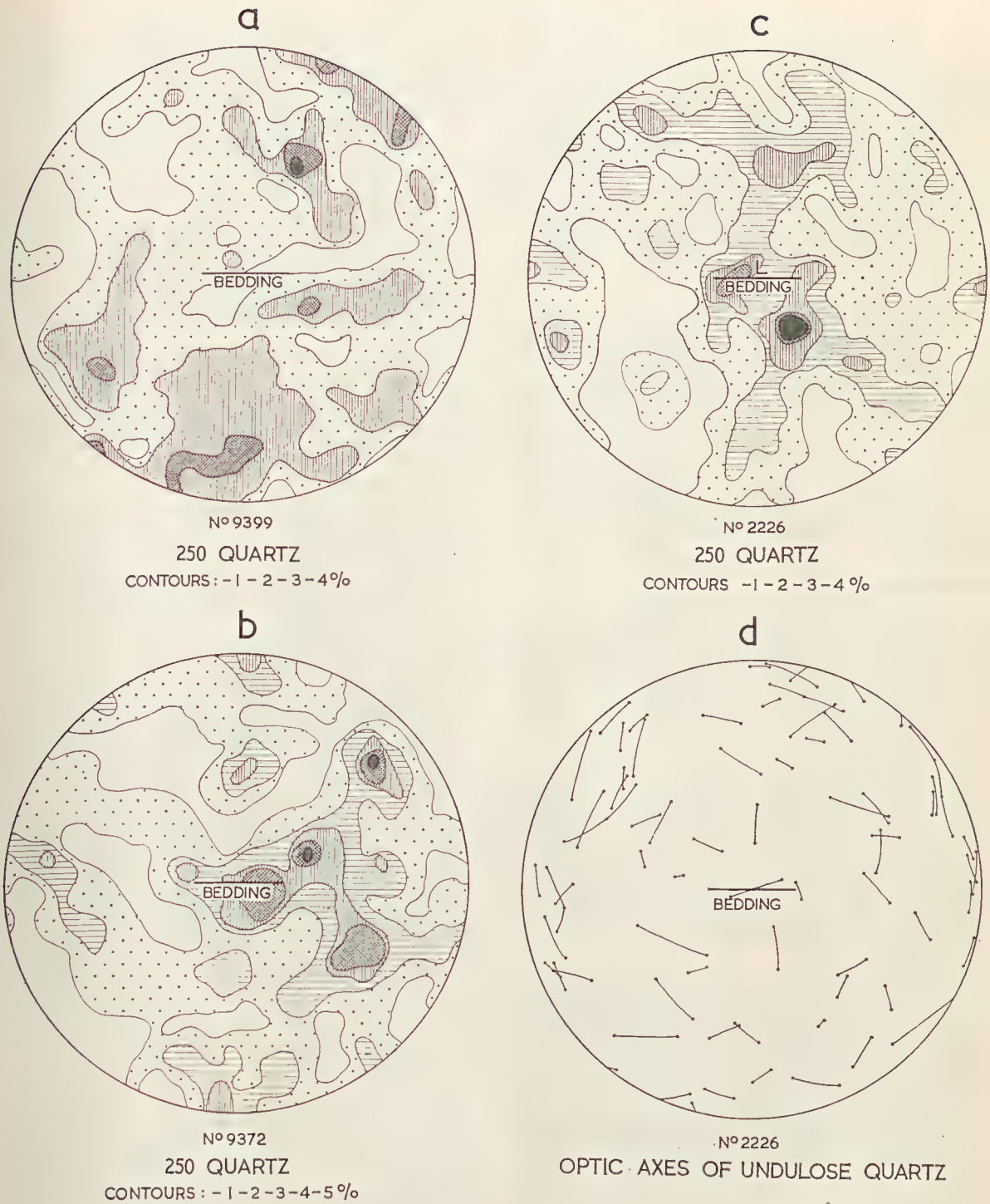


FIG. 8.—Petrofabric analyses of some Donaldson Group quartzites.

No. 9387 represents the Gutherie Quartzite on the south bank of the Pieman, at the big bend half a mile east of Hell's Gates. It is a grey, finely grained, somewhat glossy quartzite. Microscopically it consists of slightly undulose quartz grains with fairly high sphericity and with an average diameter of 0.15 mm. The rock is more deformed than most Donaldson Group quartzites as the quartz cement and the boundaries of the grains have been shattered and granulated. A quartz vein cutting the rock is also undulose and shattered but clastic fragments of chert are still recognisable. A weak foliation is outlined by sparse sericite flakes and there is accessory tourmaline.

Nonesuch Slate: 100'+

The Gutherie Quartzite is overlain by a hundred feet or so of black slate which has its type section at the eastern part of the large bend on the Pieman half a mile east of Hell's Gates where it is well exposed in cliffs. This formation is named after the Nonesuch Creek, a tributary of the Savage, shown in Fig. 6. It seems to be the youngest formation of the Donaldson Group to be exposed as the next bed to the east is the Delville Chert on the other side of the Delville Fault. The Nonesuch Slate is dark grey with bedding (in parts graded) commonly obscured by an oblique cleavage. The thickness appears to be in the order of 200 ft.

Rupert Beds

Spry and Ford (1957) gave the name Rupert Beds to a group of quartzites, slates, conglomerates and dolomite between Pieman Heads and Rupert Point. The lithological similarity to the rocks at Mt. Donaldson was noted. Mapping now shows that the rocks are equivalent as both are in a similar stratigraphic position, i.e., they overlie the Interview Slate on opposite sides of an anticline. The name Rupert Beds will no longer be used.

The sediments along the coast consist of a sequence about 1500 ft. thick of quartzites, 3 conglomerate horizons, phyllites and a thin dolomite. There are striking similarities between the conglomerate specimens 9353 from the "Rupert Beds" and the Gates Conglomerate from the Donaldson Group; the phyllite 9397 from the "Rupert Beds" and 9105 from the Donaldson Group; and the curiously pigmented quartzite of 5792 from the "Rupert Beds" and 9350 from the Donaldson Group.

No. 9353 is the conglomerate from the Donaldson Group south of Rupert Point. It is medium grey in colour, with flaky pebbles of phyllite and rounded pebbles of quartzite in a phyllitic matrix, Microscopically it consists of fragments of very finely grained argillite and quartzite in a matrix of sand-size quartz grains which are undulose, well-rounded and have a high sphericity and which in turn are surrounded by finely grained quartz and sericite. Thermal effects of the nearby Devonian granite are seen in the slight recrystallisation of the matrix and the growth of biotite and muscovite.

A quartzite (No. 9372) from the Donaldson Group at Rupert Pt. is a white to grey rock, with a slight fissility along the bedding planes shown by smears of silvery sericite. A weak lineation is present as the ribs on the foliation planes. Under the microscope it is seen to consist of ragged, somewhat lenticular, undulose grains of quartz averaging 0.3 mm. in diameter but ranging up to 1.5 mm., set in a matrix of finely grained quartz (about 0.04 mm.) with blurred crystal outlines. The foliation is shown by sparse, parallel sericite flakes; accessories are zircon and tourmaline.

The dolomite just south of Rupert Point occurs near the top of the Donaldson Group but was not found at Mt. Donaldson. No. 9346 is a massive dark grey rock laced with white carbonate veins. In thin section it is finely grained but with an uneven texture due to slight recrystallation, it consists almost entirely of dolomite with a little clastic quartz, zircon, iron ore and rutile. The grain size ranges between 1.2 mm. and about 0.005 mm.

The Savage Dolomite—Delville Chert—Bernafai Volcanics—Corinna Slate Assemblage

These four lithological units occur in a block bounded on the east by a fault-contact against Whyte Schist and on the west by a fault-contact against the Donaldson Group.

Savage Dolomite

Massive fawn to grey dolomite with some minor interbedded slate outcrops on the Pieman River for several hundred yards east of its junction with the Savage River and a few outcrops occur up the Savage River. Dolomite occurs in the upper part of the Delville Creek and has been found in diamond drill holes at the Delville-Newdegate Creek saddle.

It has been silicified to a massive chert in some parts and silicified oolite occurs a quarter of a mile east of the Pieman-Savage junction.

Specimens numbered 9365 and 9356 are typical. These are fine, evenly grained rocks with a mottled or patchy colouration which causes the rock to appear to be composed of angular fragments of a creamy colour in a grey matrix. Under the microscope, the rock is seen to be composed entirely of shapeless dolomite grains ranging in size from about 0.01 mm. to almost 2 mm. with rare quartz grains. The only variation is in grain size and hence in colour; the rock contains an abundance of finely grained (hence darker coloured) shapes surrounded by somewhat coarsely grained (thus lighter coloured) carbonate. The shapes are very variable, ranging from circular, annular, arcuate, rectangular to nebulous. This is probably due to the incomplete recrystallisation of the dolomite.

The thickness of the bed is not known; it does not seem to be more than few hundred feet but its top is not present and it is probably equivalent to the thick dolomite at Smithton, &c.

Delville Chert

Black slaty chert and quartzite outcrop on a small but prominent hill on the southern bank of the Pieman about three quarters of a mile south of the Savage River junction. Similar rocks occur on the ridge just east of the lower part of the track from the Pieman up to Mt. Donaldson, on the Pieman just east of its junction with the Whyte River and in Newdegate Creek west of the Delville Saddle.

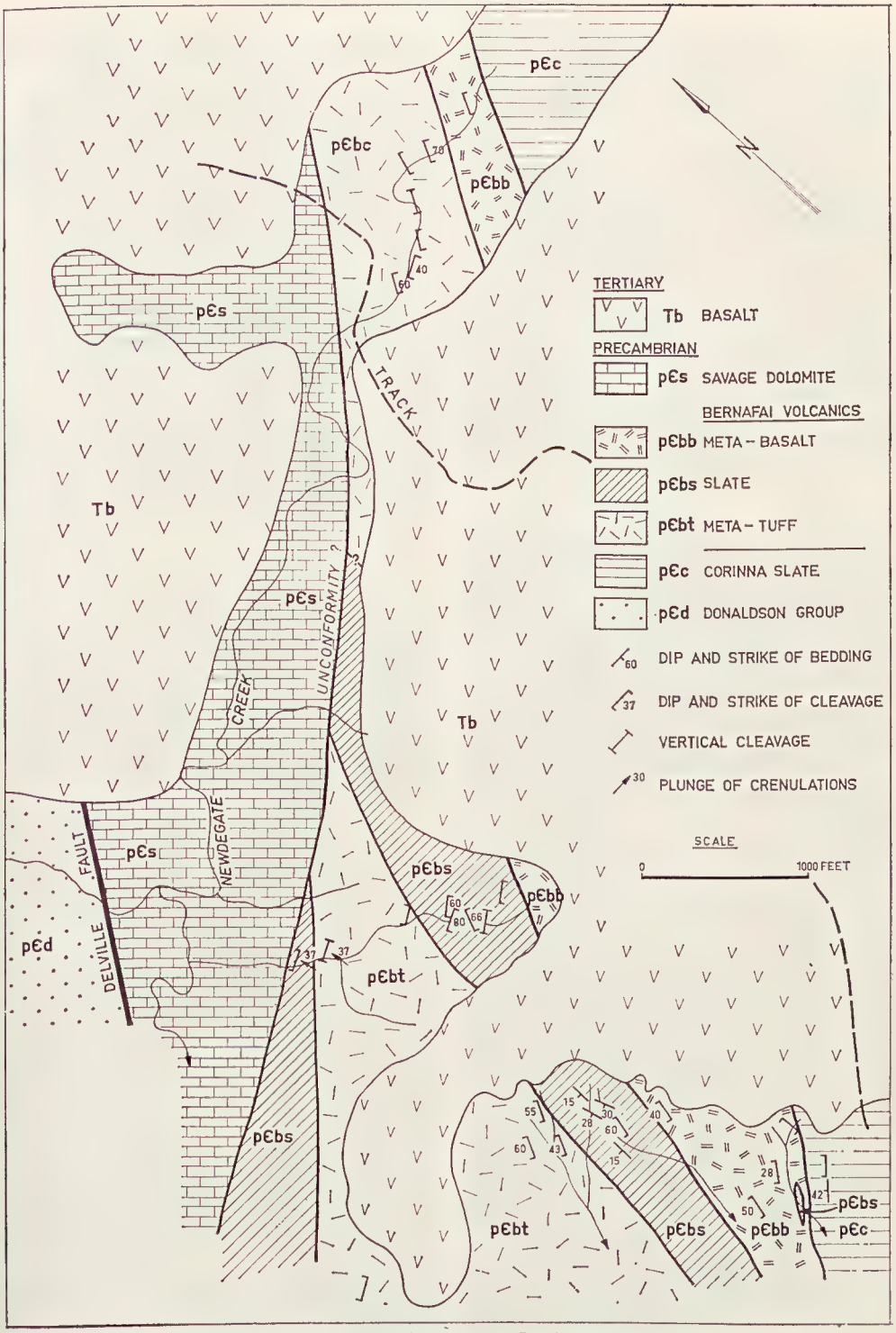


FIG. 9.—Bernafai Volcanics near the Delville Saddle (top left-hand corner of map) showing intercalations of slate. (Geology by A. Spry and R. P. Mather.) The Savage Dolomite appears to lie unconformably on the Volcanics.

The Chert lies between Savage Dolomite to the west and Bernafai Volcanics to the east both on the Pieman and along the strike 3 miles to the south at the Delville Saddle. The formation appears to be of secondary origin and to consist of silicified slate and dolomite.

No. 9352 is a black, rather fissile rock which outcrops on a small promontory on the south bank of the Pieman, 1 mile south of the Savage River mouth. Microscopically it simply consists of extremely finely grained quartz and haematite. The opaque mineral is distributed as patches and lines of tiny granules which, in parts of the rock, give a foliated texture and look very much like a residual slaty structure. This suggests that the rock is a silicified slate.

A rusty black rock with the general appearance of a weathered slate (No. 9363) which outcrops just east of the Whyte River on the northern bank of the Pieman is similar, as is No. 9261, a black, massive chert cut by abundant thin quartz veins on the hill east of the beginning of the Mt. Donaldson track.

Bernafai Volcanics

A thickness of 1300 ft. of rocks of greenish grey colour with a distinct cleavage are exposed in the Pieman River where it cuts the Bernafai Ridge and Ahrberg Hill just west of Corinna. These rocks form a long ridge and are exposed again in the Middleton Creek and Savage River to the north, and near the Delville Saddle to the south.

There are two main rock types in this formation, a tuff and a lava. Both have been so deformed as to obliterate all but the coarsest feature of the original textures and their texture is dominated by a cleavage but they still show sufficient of their original nature to indicate a volcanic origin. The characteristic mineral assemblage is albite-epidote-chlorite-tremolite.

At the Pieman River section the lower 400′ is tuffaceous and the upper 900′ of basaltic origin but the proportion of tuffaceous and normal slate increases to the south (see fig. 9).

No. 9270 is a fine-grained banded rock with a cleavage oblique to the bedding, outcropping in the Savage River where it turns west to cut across the ridge extending north of Ahrberg Hill. It is a greenish mottled rock with coarsely and finely grained bands some of which contain clastic fragments up to 1 cm. across. Under the microscope the more finely grained bands are seen to consist of a mass of parallel needles of fine tremolite with tiny granules of epidote and zoisite, flakes of biotite, albite, and ilmenite grains rimmed with sphene. Chlorite forms small clots. The coarser bands contain less epidote, more albite and much more chlorite and in addition, scattered large (0.2 mm.) grains of quartz of clastic origin. This rock is the result of low grade regional metamorphism on a tuff which was dominantly composed of basic igneous material with a little normal clastic material admixed (Analysis 6 in Table II). A foliation produced by parallel amphibole laths is oblique to compositional layering in No. 2208 (Plate I, No. 5).

The basaltic member is represented by specimens 9307 and 9357 from the south-eastern side of Ahrberg Hill; 9410, 9391, 9305, 9317 and 9331 from the Pieman River end of Bernafai Ridge; 9335 from the Middleton Creek where it cuts the northern end of Ahrberg Hill; 9278, 9291 and 9282 from the Savage River north of Ahrberg Hill; 9409 from the Whyte River, 1 mile above the Pieman; 9262 from the Pieman River immediately east of the Whyte junction; 9398 from the Pieman River immediately east of the Whyte junction; 9398 and 9402 from the Corinna-Zeehan track about 1½ miles south of Corinna.

No. 9305 is from the type locality on the Pieman River at Bernafai Ridge. It is a light greenish grey in colour with a moderately well developed cleavage. Ovoid bodies up to a centimetre across are taken to be relict amygdales. Under the microscope the rock is finely grained and consists of pale tremolite-actinolite, albite, and zoisite. The amphibole occurs as rather large laths (0.15 mm. x 0.1 mm.) which are pleochroic from colourless to pale green and tend to be at an angle to the foliation produced by the preferred orientation of smaller (0.1 mm. x 0.02 mm.) fibrous, medium-green amphiboles. Albite also occurs in several different forms; the larger crystals (about 0.1 mm. diameter occur as bands and lenses and are rather dusty with albite-twinning shown by a few individuals. Irregularly shaped, fresh untwinned albite is abundant as tiny crystals about 0.05 mm. across. Tiny granules of zoisite are abundant and possibly also some epidote. Elongate and lenticular aggregates of finely granular sphene or leucoxene are present. No. 9391 from this locality is similar except that it contains abundant yellow epidote together with some green chlorite and a little bright green biotite. The amygdales consist of radiating fibrous epidote with a core of chlorite. Relict amygdales in 9402 contain epidote (Plate II, No. 6).

No. 9307 from the western side of Ahrberg Hill is similar but contains a little muscovite. No. 9335 from Middleton Creek, like several other specimens, is rich in ferromagnesians and contains only a little albite; this specimen, and also some of the others which lack amygdales may have been tuffs.

Rocks similar to those of Bernafai Ridge and Ahrberg Hill outcrop at the Whyte-Pieman junction and for over a mile up the Whyte River. No. 9409 which outcrops on the Whyte River a mile above its junction with the Pieman shows relict basaltic texture. In the hand specimen it is a pale green rock which is generally massive but with a weak cleavage. Microscopically it is finely grained and consists chiefly of albite, yellow epidote granules and amphibole needles and laths, with a little chlorite. The albite occurs as parallel laths instead of the usual shapeless crystals and these range up to 1 mm. across in size. The feldspar is irregularly twinned, fractured and contains epidote grains; the larger crystals can be seen in an arrested stage of breakdown to aggregates of smaller crystals.. A vein of epidote cuts the rock and magnetite is abundant. This rock is very similar to the rock from the southern end of Four-Mile Beach. This has an irregular texture with large crystals of albite up to 0.5 mm. across in a foliated matrix of actinolite (0.2 mm. x 0.01 mm.) and yellow epidote (0.5 mm.). The reticulate

and radiating needles of pale-green actinolite through the feldspar are typical and are also shown by 9409.

No. 9262 is a light coloured, soft rock with a strong cleavage parallel to irregular and lenticular banding, outcropping just east of the Pieman-Whyte confluence. Under the microscope the rock is seen to consist of thin bands alternately rich in chlorite or in pale actinolite needles; albite and a little zoisite are also present and a little biotite occurs in some layers. Some bands are strongly contorted and an oblique fracture cleavage has developed.

The Bernafai Volvanics change in lithology towards the coast; tuff becomes more abundant than lava and beds of non-volcanic pelite are interbedded. The pelite beds are of glossy grey crenulated slate, identical with the Corinna Slate.

Chemical analyses given in Table II suggest that the lavas were originally olivine basalts and show the tuff to be similar to the lava but with a quartzose addition. Possible relations with the amphibolites intruding the Whyte Schist, dolerites intruding Interview Slate, and lavas in the Dundas Group are discussed later.

Corinna Slate

The term Cornna Beds was used by Spry and Ford (1957) to refer to rocks of differing types in the Corinna area and along the Corinna Road. It is recommended that such use be discontinued because the rocks embraced by the term Corinna Beds include those which are now called the Whyte Schist, the Savage Dolomite and the Bernafai Volcanics together with the slates at Corinna itself. The term Corinna Slate is now used to refer to that formation of banded slaty siltstones and slate which occurs along the Pieman River between Corinna and Bernafai Ridge.

No. 9334 outcrops on the northern bank of the Pieman, about a quarter of a mile west of Corinna, just below the Bernafai Volcanics. It is a grey, thinly bedded rock with a weak cleavage at an angle to the bedding. Microscopically, it is very finely-grained and consists chiefly of quartz and parallel sericite flakes with lesser chlorite. Iron-ore and tourmaline are accessories.

Specimens 9383 outcropping 200 yards west of the Whyte-Pieman junction, and 9354 from 1 mile up the Whyte are similar. They consist of thin layers alternately rich in quartz or in sericite; the parallel micas impart a cleavage. Chlorite is present and accessories are sphene and tourmaline.

The Corinna Slate near the coast (in the Delville Saddle area) is similar except that is richer in iron-ore (5-10%) and contains epidote (e.g. 2216). The cleavage of the slate is commonly crenulated with a fracture cleavage along the axial surface of the crenulations (e.g. 2231).

Beds of quartzite a few feet thick are interbedded with the Corinna Slate in the Newdegate Creek. These (2211, 2230) are pale, greenish grey, finely grained rocks consisting of granular quartz (0.05 mm.) and about 20% of parallel green chlorite flakes (0.2 mm.).

STRUCTURE

This whole area of Precambrian rocks forms a major structural high (Rocky Cape Geanticline) separated from the Tyennan Geanticline to the east by a structural low of Palaeozoic rocks. The Whyte Schist belt forms a minor high with younger sediments flanking it on each side and the axis of this structure swings in an arc from east-west at the coast just north of Granville Harbour around to north-south at Browns Plains (north of Corinna), and to a little west of north along the Savage River west of Long Plains.

The different rock types are distributed in a series of belts which are separated in some cases by faults and it is thus difficult or even impossible to determine the relationships between the rocks in each. The minor structures (cleavage, lineation) and the minor folds are not genetically related to the major folds which apparently were formed after many of the minor structures. The major faults are however parallel to the folds and thus some may be related to them; as one fault cuts Devonian granite at Conical Rocks it is probable that some major structures belong to the Tabberabberan Orogeny.

The major structure across the Eureka Plains and extending from Zeehan to Granville Harbour and to the Meredith Range is the Pine Creek Syncline which is more than 10 miles across. The fold is related to the Duck Creek Syncline (Blisset 1960) and is probably, at least in part, a Devonian structure. Ordovician to Silurian sediments overlie the Oonah Quartzite with an unconformity of small angle and a major unconformity is inferred between the Oonah Quartzite and the Dundas Group and later sediments because of the greater deformation of the Oonah Quartzite and structural discordance at the boundary.

A stereographic plot of poles to the major foliation in the Whyte Schist (fig. 11d) shows that the foliation has been folded into an anticline plunging at 45° towards the south east. Bedding is visible in very few outcrops of the Whyte Schist and is restricted to the less altered varieties south of Stringer Creek. Study of thin sections indicates the presence of four S-surfaces in some rocks with the major one S_2; it is generally easy to recognize S_2 macroscopically but from the appearance of S_1 under the microscope there is doubt whether it could be recognized macroscopically. This suggests that the mapped foliation is partly S_0 (bedding) and partly S_2. It appears likely that the strike of S_2 does not differ markedly from that of S_0 on a large scale as the lithology (pelite with quartzite) at the coast north of Duck Creek continues to the east in the direction of the foliation and occurs on the Pieman River. Many of the schists and phyllites show crenulations of the foliation (S_2) up to an inch or so across. Some are symmetrical chevron folds with a fracture cleavage (S_3) along the axial surfaces; others are asymmetrical with a fracture cleavage along the appressed limb. Just south of Stringer Creek in the Pieman, a well foliated amphibolite is crenulated in a similar manner.

Somewhat similar crenulations occur at the north Pieman Head in sediments regarded as younger Precambrian. These crenulations will be

shown later to have been refolded, thus the crenulations together with S_3 may be late Precambrian (Penguin) or Cambrian (Tyennan).

At least one foliation, and in places, two lineations are present in the Oonah Quartzite. Small isoclinal folds are common and the rocks are cut by abundant quartz veins.

The strike of bedding between Granville Harbour and Zeehan is about 290° with rather steep dips to the north but an equal-area projection of 250 poles to bedding across the whole area reveals a pattern (fig. 10) which is not understood at present. In general terns it represents a large fold (Pine Creek Syncline) plunging at about 60° towards 120° but the poles to bedding do not fall on a simple great circle. The pattern might be interpreted as two partial great circles representing fold axes at pts. A and C in fig. 10 but more likely represent either a non-cylindroidal fold or a cylindroidal fold which has been somewhat refolded. This is supported by a study of the distribution of the poles to 34 fold axes measured in the region between Granville Harbour and Zeehan. The scatter in directions is considerable and the poles to the Pine Creek Syncline and the nearby known Tabberabberan folds (Zeehan Basin and Duck Creek Syncline) are plotted for comparison. The small folds in the Oonah are isoclinal and differ in style from those in the Palaeozoic rocks. They probably consist of more than one generation because discordant folds of different size and style occur in a quarry on the Corinna Road, 2 miles beyond the Montana Mine. The Pine Creek Syncline is probably later than the isoclinal folds but from its abrupt discordance with the Zeehan Basin is unlikely to be wholly Tabberabberan. The scatter of small-scale fold axes and irregularity of outcrop patern suggest that the area was affected by perhaps Penguin, Jukesian and Tabberabberan movements.

The structure further west is more complex as is shown in Fig. 5 but generally speaking, an anticlinal axis trends at 40° through the Tikkawoppa Plateau, Mt. Donaldson and the Longback Range. This belt contains a series of **en echelon** folds trending at between 150° and 200° with flat southerly plunges.

A series of open folds whose axes are nearly horizontal and trend about 35° occupy the crest of a major anticline between Corinna and Pieman Heads.

Small scale folds may be mapped in the more open country around Mt. Donaldson and Fig. 6 shows them to have a complex pattern. Most important of these is the overturned anticline which crosses the Pieman near Hell's Gates. This is really an asymmetrical and overturned crumple on the eastern limb of a large anticline whose axis lies to the west; it cannot be followed for any distance away from the river and the overturning is probably quite limited. Strong drag folding occurs in the overturned beds just east of Hell's Gates just above river level.

The structure on the Plateau to the south consists of an anticline whose axis has a 170° trend about 1 mile south-south-east of Hell's Gates, swinging around to 190° further to the south.

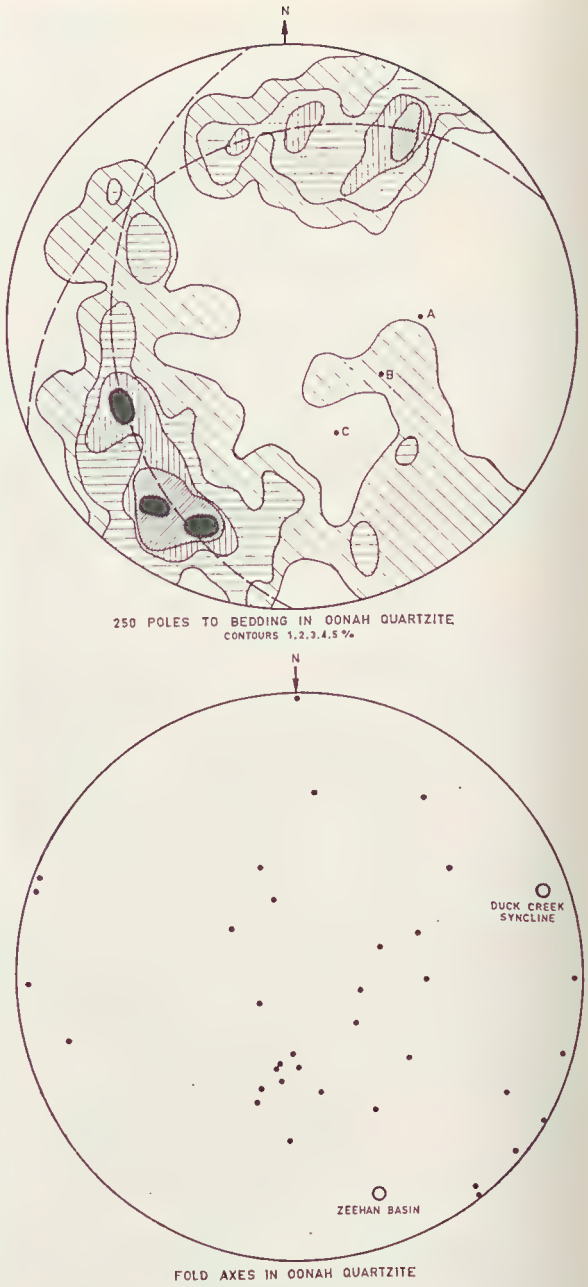


FIG. 10.—Structure of the Oonah Qartzite and Slate. (*a*) Poles to bedding. The Pine Creek Syncline is outlined. It is possible that the distribution represents two folds (shown by the great-circles) but it is probable that a single, major, non-cylindroidal fold is present. (b) Irregular distribution of fold axes; apparently unrelated to the Pine Creek Syncline or the nearest Palaeozoic folds (Duck Creek Syncline and Zeehan Basin).

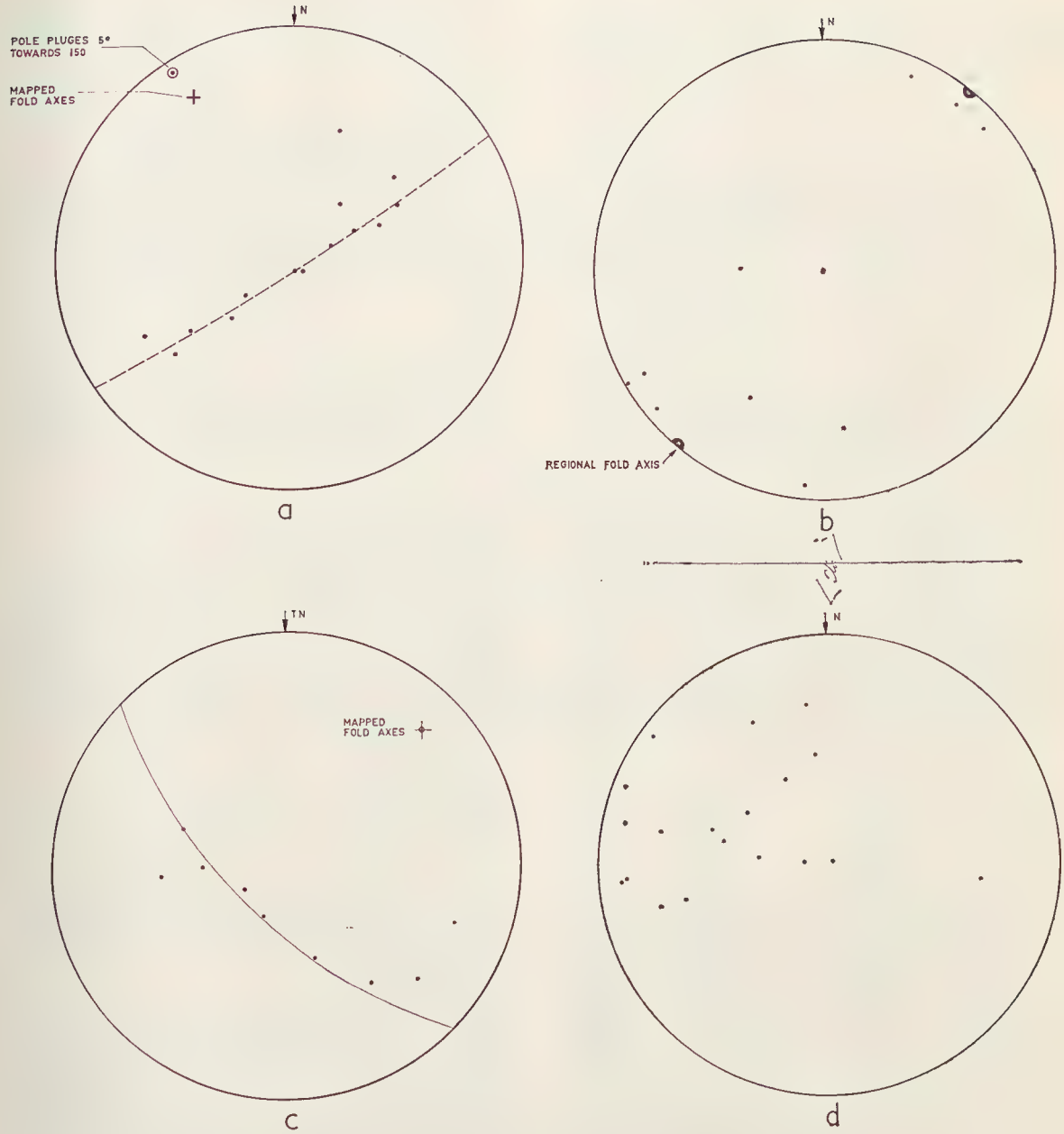


FIG. 11.—Structure of the Donaldson Group. (*a*) Poles to cleavage in slates east of Mt. Donaldson tend to lie on a great circle whose axis is close to the direction of mapped folds. (*b*) Lineations in quartzites at Hell's Gates are irregularly distributed and are probably only fortuitously near the mapped fold axis. (*c*) Lineations at Rupert Point tend to lie on a great circle whose pole is close to the direction of mapped fold axes. (*d*) Poles to foliation in Whyte Schist.

The structure in the button-grass slopes to the south and east of Mt. Donaldson was mapped by walking the outcrop of marker beds such as the conglomerates. This revealed a large anticline plunging at about 30° towards 200° through the peak with a series of small anticlines and synclines whose axes plunge at about 10° towards 130°-150°.

Relation of minor to major structures

The major structure of the area was determined by mapping rock distribution because it was found that the orientations of minor structures were very variable. The beds in the Donaldson Group at Mt. Donaldson and Rupert Point possess a sporadic lineation (crenulation in the pelites and boudinage, mullions, and tight folds in some quartzites) and a cleavage at an angle to the bedding. Mapping shows that the cleavage is not parallel to the axial surfaces of the larger folds nor are the lineations parallel to the axes. The structural picture is by no means clear but evidence of several periods of folding seem to be present and a very brief study of the rocks along the Donaldson River, at Hell's Gates, near Rupert Point, and east of the summit of Mt. Donaldson throws some light on the problem and points the way for future work.

A stereographic plot of the poles of cleavages (fig. 11a) in slates east of Mt. Donaldson shows that although the cleavage direction is widely variable in dip and strike, the poles appear to lie along a great circle. The pole to this great circle plunges approximately at 5° towards 140° and as the independently mapped folds have axes plunging at about 10° towards 150°, it appears that the cleavage is an older structure which has been folded by these folds.

A similar relationship is shown by the lineation in the Donaldson Group rocks between the Pieman Heads and Rupert Point (fig. 11c). The poles of the lineations are scattered but lie on a great circle whose pole plunges at 20° towards 35°. This is close to the direction of the regional folds in this area and it would seem that the lineation is older than the regional folds and has been folded by them (Ramsay, 1960).

In the two examples given above, the newer folds are oblique to the older structural trends so that it is possible to separate them, but at Hell's Gates, it seems that the older and younger trends are approximately parallel thus causing the disruption of the older structural pattern to be incomplete. Fig. 11b shows a plot of the lineations at Hell's Gates and although there is a considerable scatter, they do not lie on any recognisable great circle but tend to cluster around an axis plunging at about 30° towards 220°. The major fold axis here plunges flatly towards 200° but there is too poor a degree of parallelism of the lineations with this direction to suggest that the lineations are cognate with the folds. Small drag folds just west of Hell's Gates have the appropriate asymmetry for this overturned limb and have axial directions between 185° and 205°; these are cognate with the large fold. The axes of the boudins in the Mametz Quartzite here swing between a plunge of 5° towards 240° to 10° towards 40° and thus appear to be older structures unrelated to the fold.

In the Nonesuch Slate in the cliffs near the small waterfall at the large bend in the Pieman, three quarters of a mile east of Hells' Gates, there is a clear example of the lack of relation between the cleavage and major structure. In one outcrop, the bedding of the slate strikes at 210° and dips south-east at 22°; the cleavage strikes at 240° and dips south-east at 5°; a fine lineation (crenulation) plunges at about ½° towards 230°. Here the cleavage is flatter than the bedding and if related to the major structure, would indicate that the slate is overturned and lies on one limb of a completely flat, recumbent fold. Graded bedding however indicates that the bed is the right way up, as does the regional mapping, thus it would appear that the cleavage was formed in a steep position and was subsequently rotated (along with the bedding) to the present sub-horizontal attitude.

The large scale folds trend at 30° generally but swing around to about 0° at the Pieman River three quarters of a mile west of the Donaldson. Dips of bedding are to the east and west at moderately high angles but the cleavage dips fairly regularly west at 65° and strikes close to the trend of the fold axes. With the limited amount of data available, the cleavage here looks as though it is parallel to the axial planes of the regional folds.

The axes of the folds around the Mt. Heemskirk granite mass are oblique to the regional trend in this area and it is possible that the granite intruded diapirically so that the folds are locally parallel to its margins. The granite is wrapped around by Precambrian sediments which dip outwards giving a domal structure with the Duck Creek and Pine Creek Synclines concentric to the granite. It is possible that hornfelses along the north-western contact of the granite, between Granville Harbour and Donnelly's Lookout might be the Whyte Schist.

FAULTS

Three separate fault systems of different kinds can be recognised in this region. The most important set trends at about 30° (parallel to the major fold axes) and divides the region up into a series of belts. Small faults trend at a mean of 15° across the plains between the Pieman, Interview and Donaldson Rivers and minor faults are associated with the small folds east of the summit of Mt. Donaldson.

Donaldson Fault Set

Spry and Ford (1957) first recognised the existence of a major fault running from Conical Rocks across the Pieman and north parallel to the Donaldson River. This fault is prominent at its south-western end where it forms the contact between the Devonian granite of Conical Rocks and the Donaldson Group ;it is recognisable a few miles north-east where it is the boundary between the Interview Slate and the Donaldson Group but is difficult to follow north of the Pieman where Interview Slate lies on both sides.

The Donaldson Fault is at least ten miles long and has a throw of probably about 500' with the eastern side down. As it shears the granite in places it is probably compressional and this is

supported by observations of joints in the faulted zone across the granite which suggest a westerly dip. It seems likely to be a thrust cognate with the regional folding. A number of smaller faults parallel to this occur further to the north-west.

Delville Fault

This runs approximately in a 30° direction but unlike the Donaldson Fault, swings considerably. The small-fold axes in the Donaldson Group, east of the summit, end abruptly at this fault. Silicified breccias outcrop on this line east of the early part of the track from the Pieman River at Mt. Donaldson. The Gutherie Quartzite and Nonesuch Slate strike obliquely into this line and then disappear. Near the Delville Saddle the Bernafai Volcanics swing around and abut against the Donaldson Group across this fault.

Nothing definite is known of the dip or displacement of the Delville Fault. It brings the younger Savage Dolomite against the Donaldson Group, thus faulting out a thickness of at least 2300′ of the Corinna Slate and Bernafai Volcanics, so that it has an east-side-down movement of 3000′+. From its curvature, it may be an old (pre-Tabberabberan) fault.

It is suggested that the contact between the Whyte Schist and the younger beds to the west (near the Whyte River-Pieman River junction) is a fault (Whyte Fault). The younger beds dip towards the older ones, and the Savage Dolomite and beds below it cut out against the schist. On the southern and eastern side of the Whyte Schist, the Oonah Quartzite and Slate appears to rest directly on the Schist but is missing on the northern and western side. This fault turns around parallel to the swing of the strike of the Whyte Schist and thus is probably pre-folding in age; it could be related to the Delville rather than the Donaldson Fault. The Whyte Fault has a west-side-down movement of extremely large magnitude, as it brings one of the youngest beds (Bernafai Volcanics) down against the oldest rock, the Whyte Schist.

Structural Conclusions

The structure of the area is complex and the history is uncertain at present but it is concluded that the Precambrian sediments have been deformed at least twice and that the most prominent cleavage in some rocks, the boudinage, the small-scale crenulations and the preferred orientation of quartz-axes are due to an early period of deformation and that these structures have been disturbed by at least one later tectonic eevnt. The Pine Creek Syncline appears to be a pre-Dundas Group structure, at least in part, but there may be a Tabberabberan element in the major folds through Mt. Donaldson and the Interview River plains as suggested by the following:

(1) the Donaldson fault which is younger than the Devonian (?) granite is parallel to the folds,

(2) these folds appear to continue to the north where they affect the Dundas Group at the Arthur River.

DYKE SWARM

Several hundred thin sheets of dolerite intrude the Interview Slate and Quartzite as shown by Spry and Ford (1957) and fig. I. These trend N.N.E.; some are apparently concordant with the sediments but others are discordant. The largest known is five miles in length; the bodies are commonly over a mile long but only about 200 feet thick.

The rocks are massive with a medium grain size and doleritic texture. Under the microscope the intergranular texture is still preserved but the pyroxene has been completely replaced by fibrous masses of yellow to olive-green actinolite. The feldspars show the original lath shapes but are now composed of cloudy albite with abundant finely granular zoisite. Much of the feldspar occurs as graphic intergrowths with quartz. Large skeletal grids of ilmenite, small flakes of brown biotite and a little chlorite are present.

Other varieties described by Ward (1911) and Spry and Ford (1957) have been sheared so that the igneous texture is partly destroyed.

The rocks are similar to the Cooee Dolerites (Spry 1957) which intrude similar sediments; the trend of the Interview dyke swarm is towards the Rocky Cape-Burnie area where the Cooee dolerites occur.

The analysis in table III shows that the rock is basic and a little richer in soda than potash; the oxidation of the iron and high H_2O values are due partly to weathering. The chemical similarity with the average of two Cooee analyses is apparent.

A dyke south of Pieman Heads has been metamorphosed by the Devonian granite and is thus pre-granite in age but other direct evidence of age is lacking. The present evidence (Spry, 1962b) indicates that the Cooee dolerites are Precambrian.

Table III

	(1)	(2)	(3)
SiO_2	48.38	49.54	46.74
Al_2O_3	14.52	16.59	14.94
Fe_2O_3	5.87	1.46	2.90
FeO	9.21	8.06	10.66
MgO	5.07	5.06	7.04
CaO	7.20	8.69	9.60
Na_2O	2.22	2.22	2.77
K_2O	1.50	2.63	0.06
H_2O+	3.40	3.19	3.54
H_2O-	0.49	0.14	0.14
MnO	0.18	0.17	0.26
P_2O_5	0.22	0.41	0.16
TiO_2	2.20	1.84	1.75
	100.46	99.00	100.56

(1) Dolerite, Interview dyke swarm, Pieman River.
(2) Average of two Cooee Dolerites (4874, 4852).
(3) Lava from the Bernafai Group.
Analyst: Tas. Dept. Mines.

It is possible that some dykes might represent feeders to the Bernafai volcanics which are interbedded with the upper part of the sedimentary succession, the base of which is intruded by the dykes. Chemically there are only slight differences between the dolerite and lava; the Bernafai lava

is less oxidized and richer in magnesia, lime and soda, but poorer in iron and potash. The dyke-rocks are generally unsheared and post-folding in age but the lavas are strongly sheared and pre-folding, however, they would appear to be of similar magma type.

CONCLUSIONS

The Whyte Schist is similar in many respects to low grade metamorphosed Precambrian rocks elsewhere in Tasmania and the sediments of the Oonah, Interview, Donaldson, &c., Groups can be correlated with unmetamorphosed sediments at Rocky Cape and elsewhere. This is the only locality, studied by the author, where the "older" and "younger" groups are in close proximity over an appreciable area.

The preferred hypothesis is that the siltstones and shales of the Whyte Schist were partly metamorphosed, intruded by sodic basic to intermediate dykes, then deformed again during the Frenchman Orogeny. After a period of erosion the Schist was overlain by the Oonah Quartzite and Slate, the Interview Beds, Donaldson Group, &c., which where folded, intruded by dolerites and folded again during the Penguin Movement. The Savage Dolomite was deposited, then the area was subjected to further tectonic movements, possibly during the Jukesian (Cambrian) and Tabberabberan (Devonian) epochs.

The area is so densely vegetated and outcrops are so poor that the critical exposures are not visible but there are a number of reasons why the hypothesis outlined above is open to debate. It is by no means impossible, at the present state of knowledge, that the Whyte Schist with its amphibolites could not be equivalent to the unmetamorphosed sediments with the dolerites.

The Whyte Schist is less altered than most other Tasmanian metamorphics and the Oonah Quartzite, Donaldson Group and Bernafai Volcanics are more deformed than many other unmetamorphosed Tasmanian Precambrian sediments. All belong to the lowest sub-facies of the Greenschist Facies and contain members of the assemblage quartz, albite, epidote, chlorite, muscovite, actinolite, magnetite and calcite.

Both the Whyte Schist and the unmetamorphosed sediments show evidence of two periods of deformation. The strip of Whyte Schist is flanked on both sides by "younger" sediments. The Oonah quartzites on the east dip to the east and are probably the oldest of the sedimentary succession. The sediments on the west dip to the east, towards the Schist, and are among the youngest in the succession (Corinna Slate, Delville Chert). This implies a very large fault along the curved western margin of the Schist. The western boundary of the Whyte Schist appears to be sharp, but it is difficult in isolated outcrops to distinguish between Bernafai Volcanics and the amphibolites from the Whyte Schist. Both consist of actinolite, chlorite, epidote, albite and quartz and both form long bodies with the same general trend.

The contact zone between the Whyte Schist and Oonah Quartzite is exposed in the Pieman River gorge and along the coast and appears to be gradational over about half a mile. This zone contains sediments identical with the Oonah Quartzite, sheared quartzites and siltstones similar to Whyte Schist but in a less altered condition, and some unaltered sediments which do not resemble any others in the district. This zone could be interpreted as being gradational between Oonah Quartzite and Whyte Schist or as a complex imbricated fault zone.

The possible equivalence of the amphibolites in the Whyte Schist, the Bernafai Volcanics and the dyke swarm of the Interview River presents a problem. The preferred interpretation is that the amphibolites are oldest; these were followed by a metamorphic period then the Bernafai Volcanics, then folding and finally the dolerites. This is supported by the following facts:

(1) Rocks from the Bernafai Volcanics contain what are interpreted to be relict amygdales thus they are effusive. Altered tuffs occur in this formation. The Volcanics form a definite stratigraphic horizon which is repeated across a fold.
(2) The dolerites are intrusive and form sills and dykes which are long (some miles), thin (up to 200 ft. wide) and appear to extend as a swarm for about 60 miles to the N.N.E.
(3) The amphibolites are discordant with the Whyte Schist in part and are thus intrusive, and occur as tabular bodies from 50 ft. to a half a mile in width and some miles in length. Together with the enclosing schists they extend for some miles to the north.
(4) The dolerites, Volcanics and amphibolites do not change character appreciably for 10 miles in a northerly direction along their length.
(5) The dolerites and Volcanics are quite similar in chemical composition but the amphibolites are much more sodic.

The best interpretation of the relations between what have been called unmetamorphosed sediments or "younger" Precambrian rocks and those called metamorphosed sediments or "older" Precambrian is that they are separated by a major tectonic and metamorphic event, the Frenchman Orogeny. However, it has not been possible to prove that an unconformity exists and that no lateral transition between the two exists. Even though the two groups differ somewhat in lithology, chemical composition and tectonic style, the possibiilty that one represents the other in a more deformed, metamorphosed and recrystallized form has not yet been disproved.

Upper Savage River

A brief reconnaissance, together with study of air photographs, aero-magnetic maps and thin sections suggests that the Whyte Schist and the amphibolites continue into the area of the Savage River Iron Deposit. Hughes (1957) considered the amphibolites associated with the iron ore to be Cambrian in age and although comparison (Spry 1962b) shows some chemical similarities (chiefly high soda), the structure under the microscope (Plate I, No. 3) is quite different from any found in a Cambrian intrusive. It seems likely that

the faulted syncline east of Corinna swings in an arc to the north-west, and that the dolomite at the savage River is the Savage Dolomite in the centre of this syncline. It could be separated from the Whyte Schist and amphibolite to the east by the Whyte Fault.

Correlation Within the Rocky Cape Geanticline

Younger Precambrian sediments near Zeehan and Corinna were tenatively correlated with the Rocky Cape Group along the North-West Coast by Spry (1962a). Support for the correlations given in fig. 12 is given below.

The lowest formation of the Rocky Cape Group appears to be the Burnie Quartzite and Slate (Spry 1957) which outcrops between Howth and Somerset; it may continue around the nose of an anticline through the Sisters Hills to the Dip Range, to become the Neasey Quartzite and Slate of McNeil (1961) and Longman and Matthews (1961) around the Arthur River, and further south to the Oonah Quartzite and Slate at the Pieman River.

The formation is exposed along almost 15 miles of coastline where it strikes perpendicularly to the coast; the thickness is not known but it must reach many thousands of feet. It consists of a monotonous succession of thinly bedded quartzites and slaty pelites. The arenites are light-coloured (grey to cream) and massive, flaggy or thinly bedded; the pelites are dark grey to black when fresh and show a cleavage which is well developed in some specimens but poorly in others. The rocks are characterized by an abundance of sedimentary structures including flow-casts, cross-bedding, graded bedding, ripple mark, mud-pellet conglomerates, scour, slumps and flame structure.

The arenites are mainly quartzose subgreywakes (Pettijohn, 1957) e.g. 6152, 6153, 7985, 7986, 7987, 7988, 7989, 7991, 7994, 7996, 7997, 8001, 8003, 8004. These are light grey to brown rocks, rather fine-grained, with an irregular fracture and a weak cleavage; clastic muscovite is common on bedding planes. Under the microscope the rocks consist of approximately 60% quartz and 25% rock fragments in 15% of sericitic matrix. The quartz and rock fragments are angular to subangular with a low to moderate sphericity. The rock fragments are composed of a fine mesh of sericite or a mixture of sericite and chlorite; some were possibly originally feldspar but most are clay-pellets and mudstone-fragments. Cleavage is more prominent microscopically than macroscopically and the matrix has been recrystallized and sheared to form thin layers of similarly oriented sericite, chlorite, haematite and carbonaceous material between the larger allogenic fragments. Twisted clastic flakes of muscovite and (less common) chloritized biotite have been rotated into parallelism with the cleavage which is near the bedding in some specimens but at a large angle in others. Some specimens with a

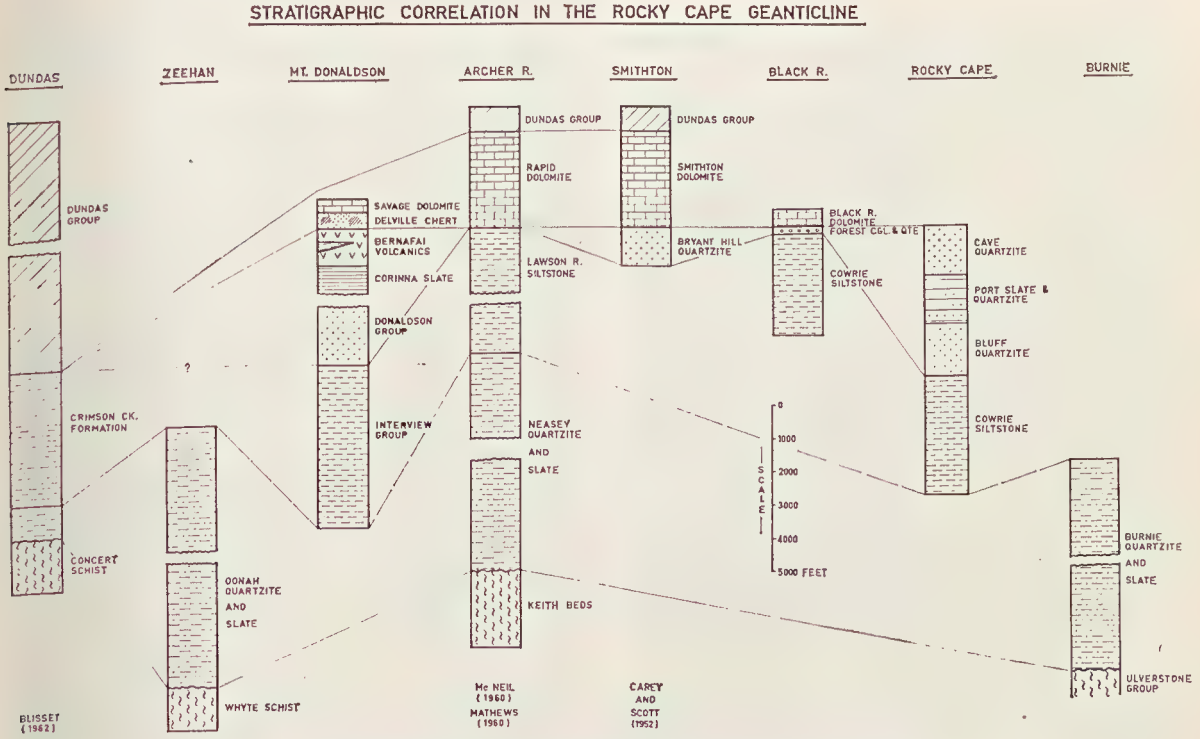


FIG. 12.—Correlations of younger Precambrian sediments within the Rocky Cape Geanticline.

weak cleavage contain quartz with a moderate sphericity and low degree of roundness. Other specimens with a strong cleavage contain quartz grains which are undulose, have deformation lamellae and are oriented with their long axis parallel to the cleavage. It is not clear whether the quartz was originally elongate and strained or whether it developed these deformation features during the production of the cleavage but as some specimens with only a weak cleavage in the matrix contain undulose quartz with lamellae it is probable that most of the clastic particles were already strained before incorporation in the rock. Some quartz has been sericitized. The common accessories are well-rounded zircon and rutile; tourmaline occurs as clastic fragments (some well-rounded, some broken across zoning) but some is authigenic (with spongy outlines or acicular overgrowths).

Dark grey quartzites such as 7988 from Wivenhoe and 6152 from Doctor's Rock and the jet black 6045 from Wivenhoe are rich in carbonaceous material. No. 7987 from Wivenhoe is typical of the micaceous and graphitic fine-sandstones. The bedding planes show abundant black patches of graphitic material about ¼" across, together with abundant muscovite flakes.

Some coarser specimens contain quartzite fragments; 7985 from Wivenhoe has fragments of metamorphic quartzite with strongly elongate quartz. Some specimens from Sulphur Creek have abundant carbonate in the matrix.

Chemical analyses (Table II) show that the subgreywacke No. 7991 is very similar to quartzites from the Oonah Quartzite and Slate.

Quartz-sandstones are uncommon in the Burnie Quartzite and Slate between Howth and Somerset. A small proportion of sandstones (such as 6047 from Sulphur Creek) consist almost entirely of quartz with a little muscovite and very little matrix. Recrystallization of at least some of the quartz forms an interlocking mosaic but some quartz grains may be original clastic grains.

The stratigraphic position of the rocks at Penguin is unknown as they are bounded by Palaeozoic sediments, Tertiary basalt and the sea. They are dominantly of quartz-sandstone and light-coloured slates and thus differ somewhat from the normal Burnie Quartzite and Slate, however it would appear that the upper parts of this formation (e.g. the quartzites at Sisters Hills) become richer in quartz sandstones. No. 8002 from Penguin consists of quartz fragments ranging from 0.04 to 0.3 mm. with a little chert, metamorphic quartzite and patches of interstitial sericite. In parts the rock is crystalline with interlocking undulose quartz but in other parts, original well-rounded quartz with high sphericity shows authigenic rims; both the grains and the over-growths are undulose. The rock contains small tight folds a few feet across and the microscopic texture reflects this deformation. The sparse sericite shows a weak foliation.

The common slates are dark grey to black, fine-grained and have a cleavage oblique to the bedding. Some are contorted and closely crenulated. Clastic muscovite flakes occur on bedding planes and many slates are carbonaceous and dark. No. 3587 from Wivenhoe is typical of the graphitic slates and is a black laminated slaty siltstone. It consists of about 40% quartz as tiny (0.02) lenticular grains, 50% sericite as parallel flakes and layers outlining a strong cleavage, and almost 10% of graphite and iron ore.

The rocks exposed in the road cutting through the Sisters Hills are possibly related to the Burnie Quartzite and Slate but the two are separated by Tertiary basalt. The majority of the rocks resemble the quartz-sandstones of Rocky Cape; they are well-cemented, vitreous sandstones with well-rounded quartz grains and a quartz-cement. Slates and black siltstones are also present. The sediments appear to pass under the Cowrie Siltstone and are thought to represent the upper part of the Burnie Quartzite and Slate.

Cowrie Siltstone

The sediments on the western side of Rocky Cape (Spry 1957, fig. 2) appear to form a regular succession and the lowermost of these was named the Cowrie Siltstone. It was considered to extend west along the coast to Black River but its unbroken continuity is not certain. At Rocky Cape it is overlain by the Bluff Quartzite then the Port Slate and Quartzite and the Cave Quartzite. The Cowrie Siltstone probably lies above the Burnie Quartzite and Slate of the Sisters Hills. Black slates, siltstones and quartzites along the coast at Cowrie Point and for many miles up the Black River are overlain by a conglomerate, chert and the Black River Dolomite at the Black River bridge.

The Cowrie Siltstone consists mainly of grey siltstone with slates and thin quartzites and is characterized by an abundance of sedimentary structures such as flute casts, cross bedding, slump structures and pyrite concretions. It is many thousands of feet in thickness.

The formation is probably equivalent to the Lawson River Siltstone of McNeil (1960) at the Arthur River, 15 miles to the south-west. Matthews (1960) described similar rocks at the Rapid River 10 miles further south. The Interview Slate and Quartzite at the Pieman River is probably also equivalent.

The rocks resemble the Burnie Quartzite and Slate in some ways but slaty siltstones are the dominant rock type and feldspar is an important constituent. The coarse siltstones near Cowrie Point (e.g. 6155) are grey, weakly cleaved rocks. They are composed of quartz (30%) feldspar (25%, albite and a little microline), muscovite (3%) in the abundant (40%) sericitic matrix. The larger clastic particles have a low sphericity and are angular. The feldspar is fresh, and the quartx non-undulose and free from inclusions; the sericite matrix is weakly foliated. Some rocks contain angular slate fragments. Well-rounded zircon, tourmaline and rutile are accessory. A little authigenic biotite has developed. Even fine-grained mudstones (e.g. 6157, 6151) contain about 20% of feldspar and clastic muscovite is present. Only about 20% authigenic sericite is present so that the rock is a siliceoue siltstone with greywacke affinites and an analysis of No. 6157 from Crayfish Creek (Table II) shows that soda exceeds potash and the iron has a low state of oxidation.

The general appearance of the texture requires comment. All of the Cowrie siltstone specimens sectioned have a distinctive appearance under the microscope and resemble low grade hornfelses. The quartz is not undulose, the feldspar is comparatively free from inclusions and the small quartz grains in the matrix have blurred interlocking boundaries. McNeil (1960, p. 50) remarked that specimens from this formation at the Lawson River "were indurated and have undergone very low grade thermal metamorphism". The cause of such metamorphism is not apparent; the formation is cut by many basic dykes but the metamorphism does not seem to change in intensity according to the distance from the dykes and there do not appear to be sufficient dykes to cause this alteration.

Bluff-Bryant Hill Quartzite

The Cowrie Siltstone is overlain by 1500′ of quartz sandstone named the Bluff Quartzite by Spry (1957). It is a light coloured quartz-sandstone with cross bedding, ripple marks and worm tracks.

In thin-section the sandstones (7912 from Bryant Hill, 7186 from Rocky Cape) consist of well-rounded quartz grains with moderate to high sphericity and a silica cement which surrounds the grains as a rim in optical continuity with the grains. A few flakes of muscovite and fragments of chert are present. Most of the quartz grains are undulose and many have deformation lamellae; the undulose extinction continues into the secondary cement. The rock is partially recrystallized with interlocking quartz crystals occuring in patches. Accessories are well rounded zircon and tourmaline.

The quartzite at Jacobs Boat Harbour and in the cliffs east of Sisters Beach is very similar and may be equivalent to the Bluff Quartzite. White quartzite with pinkish spots about ¼" across is common; a thin section shows that the spots are due to pigmentation by haematite. Similar rocks occur at Mt. Donaldson and Rupert Point in the Donaldson Group which is probably the equivalent of the Bluff and Bryant Hill Quartzites. No. 6158 consists of quartz grains 1.5 mm. across, a few flakes of clastic muscovite cemented by a film of sericite and about 15% of haematite as irregular, intergranular masses.

The Cowrie Siltstone at the Black River Bridge on the Bass Highway is overlain without angular discordance by about 75′ of white quartzitic conglomerate followed by a similar thickness of quartz sandstone. This is overlain by a few tens of feet of chert then the 100′ + Black River Dolomite (Gulline 1959). It is proposed to name this formation the **Forest Conglomerate and Quartzite** from the village of Lower Forest near which the rock occurs. It is probably equivalent to the Bluff Quartzite. The chert and dolomite is correlated with the Smithton Dolomite and the Savage Dolomite.

The Cowrie Siltstone appears to be overlain by the 1300′ + Bryant Hill Quartzite (Carey and Scott, 1952; Gulline, 1959) near Smithton. The Bluff Quartzite is lithologically identical with the Bryant Hill Quartzite and they are considered equivalent.

The Donaldson Group near Corinna is similar in lithology to the Bluff Quartzite and the overlying Port and Cave formations. The Donaldson Group follows the Interview Slate and Quartzite which is thought equivalent to the Cowrie Siltstone.

Port Slate and Quartzite

Approximately 1500′ of thinly bedded quartzite and slate overlie the Bluff Quartzite at Rocky Cape. The argillities are grey to black, laminated and contain sandy lenses, mud pellet conglomerates and slump structures. The sandstones are cross-bedded and ripple-marked quartz-sandstones like the Bluff Quartzite.

Cave Quartzite

The Cave Quartzite is the youngest formation at Rocky Cape. It is more than 1500′ thick and is lithologically indistinguishable from the Bluff Quartzite. It dips into the sea and its upper limit is not visible. A specimen (6111) from just north of the jetty at the old port is a fine-grained grey quartzite with flaggy bedding and ripple marks. In thin-section it is well sorted and consists of well-rounded quartz grains with high sphericity and roundness ranging from 0.04 to 0.6 mm. with the majority 0.1mm. across. The quartz grains in part of the rock have a quartz cement in optical continuity with the grains but in other parts the grains have sutured margins, are elongate and interlocking and have been partly recrystallized and deformed.

Smithton Dolomite

A very thick dolomite with interbedded chert and minor limestones outcrops around Smithton and has been described by Nye, Finucane and Blake (1934), Hills and Carey (1949), Carey and Scott (1952), Hoskings and Hueber (1954), Spry (1962a) and Gulline 1959). It is several thousand feet thick and varies from light grey to cream. The coarse-grained varieties tend to be thickly bedded whereas the finer grained tend to be thinly bedded. Silicification has produced white and grey cherts from massive dolomite, and rocks resembling cherty conglomerates from oolitic limestone (Carey and Scott, 1952). Nye, Finucane and Blake (1934) included an identification of crinoid ossicles by Chapman but it has not been possible to confirm this. The dolomite, (e.g. 5483) in thin section is generally dark, fine-grained and structureless but partial recrystallization has produced irregular patches of coarser, paler crystalline dolomite. Oolitic dolomites are not uncommon and these contain simple and multiple oolites in which most, if not all, of the internal structure has been destroyed.

The Smithton Dolomite overlies the Bryant Hill Quartzite at Smithton with **apparent** conformity but dolomites which are correlated with the Smithton overlie other formations, implying a regional unconformity. To the south of Smithton the dolomite overlies Cowrie Siltstone; McNeil (1960) found at the Arthur River that the Rapid River Dolomite (correlate of the Smithton) overlay the Lawson River Siltstone (correlate of the Cowrie). The Black River Dolomite (correlate of the Smithton) overlies the Forest Conglomerate

and Quartzite at the Black River Bridge. Detailed mapping of the contact between the Savage Dolomite and the Bernafai Volcanics at the Delville Saddle also indicates discordance.

Conclusions

The Burnie Quartzite and Slate is similar to the Oonah Quartzite and Slate. The Cowrie Siltstone resembles the Interview Slate which is overlain by the Donaldson Group with which may be correlated the Bluff, Bryant Hill and Cave Quartzites, plus the Forest Conglomerate and Quartzite and the Port Slate and Quartzite. A small quantity of amygdaloidal basic igneous rock at Sulphur Creek (Spry 1957, p. 90) might possibly be equivalent to the Bernafai Volcanics. These rocks mentioned above are overlain unconformably by the Smithton and Savage Dolomites which are lithologically very similar and presumably equivalent. The dolerite dyke swarm at the Pieman Heads appears to continue through to the North West Coast where members have been described as the Cooee Dolerites.

ACKNOWLEDGMENTS

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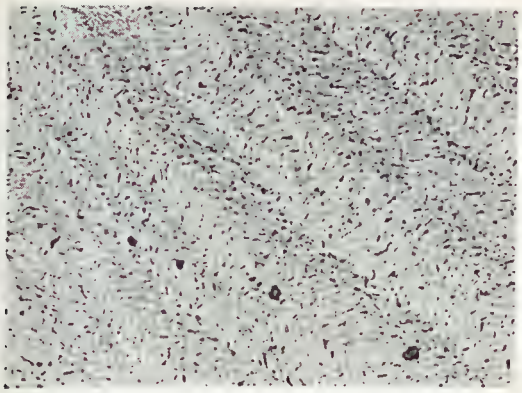

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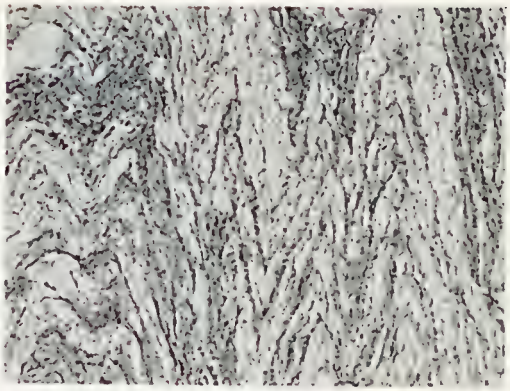

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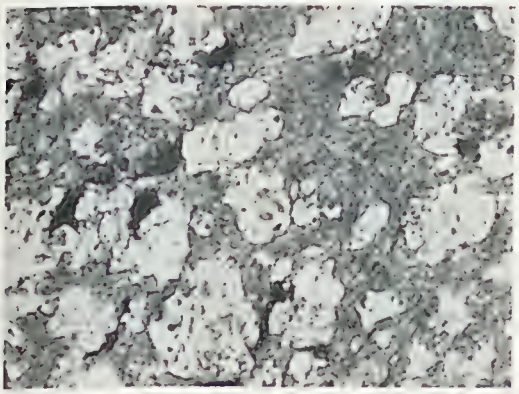

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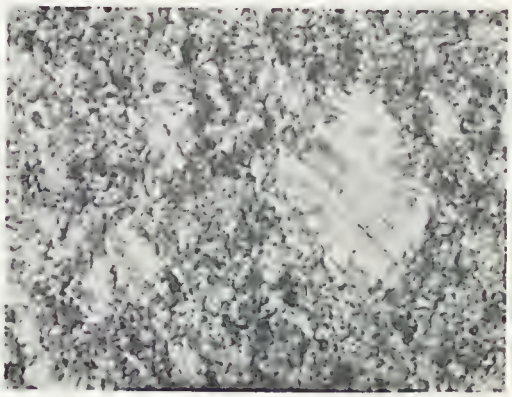

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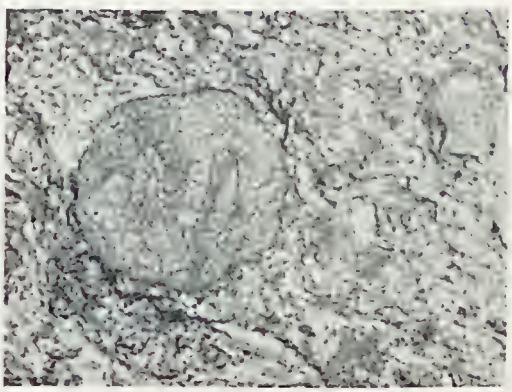

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Plate I—

No. 1.—Whyte Schist (No. 9371). Foliation crenulated to give a fracture cleavage. Bedding not visible. x 17.

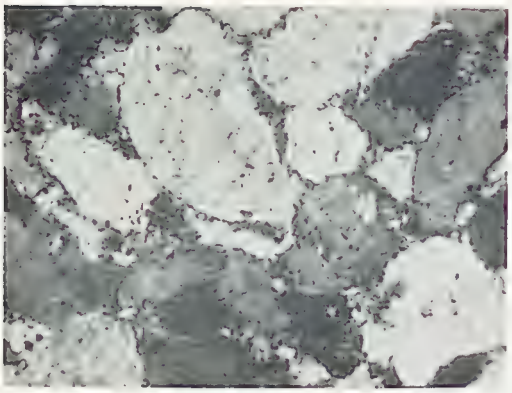
No. 2.—Whyte Schist (No. 8129). Strongly crenulated foliation is probably S_2. x 7.

No. 3.—Amphibolite from Whyte Schist (No. 9401). Round crystals of albite in foliated amphibole. x 35.

No. 4.—Altered basalt from Bernafai Volcanics (No. 9409). x 12.

No. 5.—Altered tuff from Bernafai Volcanics (No. 2208). Foliation due to parallel amphibole needles is oblique to compositional layering (bedding). x 12.

No. 6.—Altered basalt from Bernafai Volcanics (No. 9402). Epidote-filled amygdale in foliated matrix. x 12.



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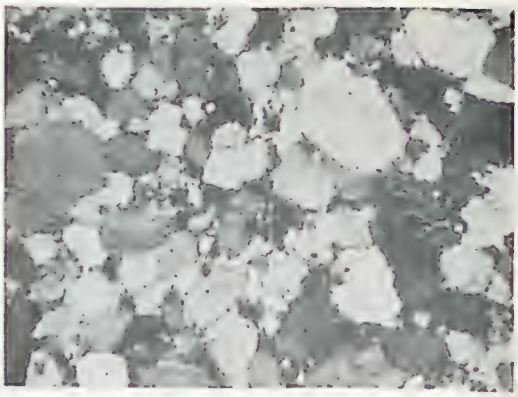

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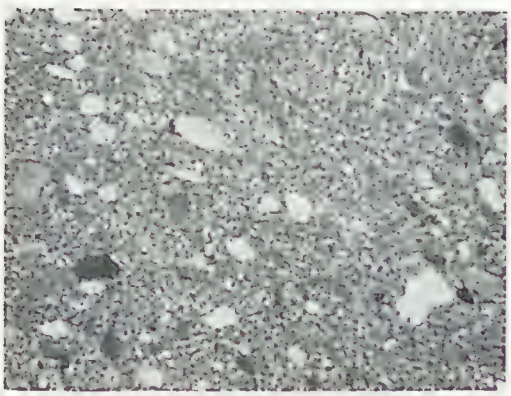

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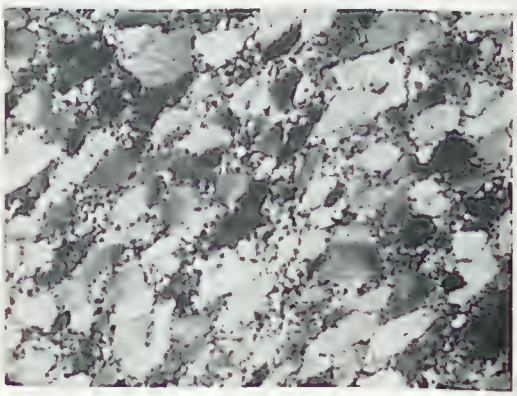

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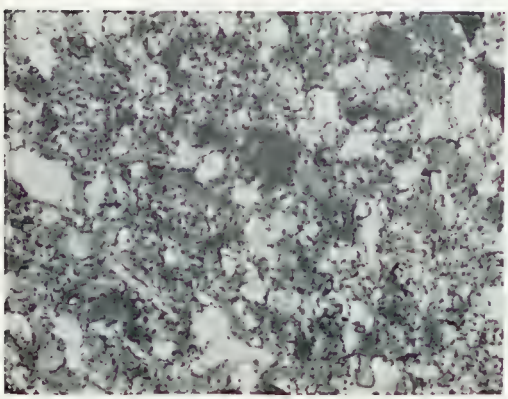

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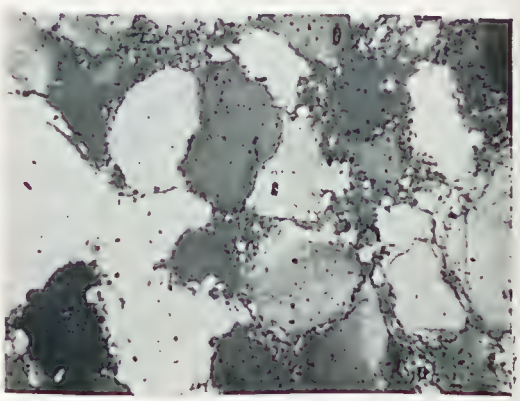

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Plate II—

No. 1.—Oonah Quartzite (No. 8025), Montana Mine, Zeehan. Quartzose sandstone type with well-rounded quartz and little matrix. x 18.

No. 2.—Quartz sandstone from Tickawoppa Quartzite (Donaldson Group) Hell's Gates. x 18.

No. 3.—Slaty siltstone, Donaldson Group (No. 9397). x 18.

No. 4.—Deformed quartzite (No. 2226) from Donaldson Group at the mouth of Newdegate Creek. x 18.

No. 5.—Oonah Quartzite (No. 8027) Montana Mine, Zeehan. Subgreywacke type with anguler quartz and clastic muscovite flakes in a sericitic matrix. x 45.

No. 6.—Tickawoppa Quartzite (No. 9295), pebbly quartz sandstone, Mt. Donaldson. x 18.

INTRODUCTION TO PROFESSOR ABBIE'S SURVEY OF THE ABORIGINAL COLLECTION IN THE TASMANIAN MUSEUM

By

W. E. L. H. CROWTHER

INTRODUCTION

The destruction of the Museum of the Royal College of Surgeons, London by enemy bombing on May 11th, 1941, destroyed not only the largest, but historically, much the most interesting of all the collection of Tasmanian skeletal remains that remained.

This group were described by Plomley, N. B. J., 1960 in a recent survey by him of all Tasmanian remains in European collections. In a letter to the writer, he describes the loss thus sustained by the Royal College of Surgeons as amounting to three complete skeletons, 34 crania, and certain long bones, apart from the skeletons, and described as relics. Fortunately only one other cranium (in Poland), was lost in this manner. As a result, the Tasmanian Museum remains as possessing incomparably the largest and most important collection of remains of this extinct Race.

Thus, the time seemed appropriate, in its Centenary Year, to have the Museum's complete craniological series classified, the more so, as to celebrate the centenary, the large collection of the writer has been deposited in the Museum to be preserved there perpetually with the other remains of the Race.

Professor Abbie consented to undertake this task and at the conclusion of his survey asked that a short historical introduction on the Tasmanian Race should be prepared for his paper and this the writer has attempted.

The Extinct Tasmanian Race

Although two excellent descriptions of this race have been given by F. Wood Jones (1936) and A. Meston (1949) and another by the writer (1934) it was soon realised that although the period 1803-1876 which covers the extinction of the race is only a short one, it would be very difficult to compress such an introduction into a small compass and at the same time serve the purpose that Professor Abbie requires.

The Era of European Exploration

Tasman, Marion de Fresne, Cook, Peron and other leaders of exploratory voyages have remarked on the natives of Van Diemen's Land, briefly or at length, according to the degree of contact they were able to make and the personal interest of the scientist or observer concerned. Only La Billiardiere the French explorer seems to have described any sustained relationship with the natives, in his expedition particularly in the localities of D'Entrecasteaux Channel and Maria Island and then only by the small ship's boats as they explored the shores and inlets.

Those who had earlier contact with the Australian aboriginals all agreed on the pronounced differences physically between the two races. The hair of the Tasmanians was differentiated as being curly and kinked in contrast to the lank hair of the Australians. They were noted also as being shorter than the Australians and perhaps more muscular. Their weapons were also different. No boomerang was known, nor the use of a throwing stick to increase the range and accuracy of their spears. Nor again were their spears tipped with stone and lastly they had no conception of the shield and its uses, and notably they did not possess any indigenous native dogs. The Tasmanians were also noted as being indifferent to the use of skins and furs relying for warmth rather on grease, red ochre and clay. Instead of canoes they were seen to use rough catamarans of bundles of dry bark, but by means of these they were observed to cross from the south coast to the Witches Islets off Maatsuyker Island and to Tasman Island; and at least one Tasmanian left his bones in the mutton bird rookeries on the steep side of Tasman Island, which remains were some 30 years ago donated to the Tasmanian Museum. Although shy and retiring and friendly in many instances, it was soon found that with little or no provocation the Tasmanians became hostile and turned to their weapons. It is now generally agreed that the Tasmanians did not possess the secret of making fire and carried embers and torches from camp site to camp site.

The Tasmanians in recent historic times

When we come to historic times it is very probable that the average settler knew little more of the native than what has been written above. In distinction from the Australians they gradually became to be classified as of a Negroid Type and of the Negrito section of the Human Race, other such types on the southern ocean being certain Melanesians, and the natives of the Andaman

Islands and New Caledonia. This theory was substantiated by anthropologists when their crania and skeletal remains became available for study and metrical examination. These deductions were strongly supported by F. Wood Jones and J. Wunderley, the former working from the hypothesis of J. H. Huxley that the Tasmanians were of Oceanic, Negrito Melanesian stock comparable to the natives of New Caledonia. Wood Jones further postulated that they had migrated to Van Diemen's Land by a precarious sea voyage rather than passing by Island to Island (since submerged) to New Guinea and finally to Australia. There the matter rested until the Harvard-Adelaide Expedition of 1938-39, which working over a large series of Australian aborigines, Australian Hybrids and Tasmanian half castes at Cape Barren Island at least 100 crania at the South Australian Museum and small series of Andamanese and Tasmanian Crania in various collections, came to the following conclusions.

That the Tasmanians were of Oceanic, Negrito stock with a large admixture of Murrayian characteristics and that they had arrived in Van Diemen's Land via New Guinea, and Australia during the fourth and last glacial Period (Birdsell, J. B., 1949). Birdsell seems to infer that the last part of this migration to Tasmania was by sea and mentions Wood Jones' theory of a migration by canoe without indicating his support for so long and precarious a passing by water with only primitive craft, not comparable to those employed by the Polynesians on their migrations.

The Period of Numerical strength of the Aborigines

Considerable attention has been given to the numerical strength of the race that entered the long contest with the settlers early last century. Opinions varied from that of Melville of 20,000 in 1803 to James Backhouse who believed they never numbered more then 1,000. G. A. Robinson whose opinion should carry much weight considered their population to have been 6-8,000 and immediately before their first European contacts to number about 2,000. Wood Jones considered even such a figure as 5,000 in 1803 would be a conservative estimate and a remarkably small one considering the length of time of their occupation of Tasmania, as by 1803 there were some 20 established Tribes with as many different dialects. Such differences between tribes with a race predominantly identical, he considers as evidence in favour of ancient settlement on the Island.

In the earliest days of the European settlement in Van Diemen's Land the relations of the races were relatively friendly, although actual contact at the settlements was infrequent. When small parties of natives did arrive they were given food, warmth, and protection and relations were satisfactory. Then came the clash at Risdon when a large hunting party took the little settlement by surprise, and in the absence of officers and social officials, panic arose and in the resultant clash a number, estimated by one, to be as many as 50 of the natives, lost their lives. This unfortunate occurrence is considered as a turning point in the relations of the two races although no doubt incidents were already occurring in the interior of the Colony. Food had been scarce, to the point of famine, and convicts and dogs were sent out to obtain the meat of kangaroo and emu. Others already were assigned as shepherds and stockmen to country settlers.

These men, isolated and not under control and supervision, ill-used the natives and interfered with their women and savage reprisals took place, and during the terms of Governors Davey and Sorell hostilities were widespread throughout the Island. Their attemps to remedy such conditions were hampered by the activities of parties of bush-rangers who were harassing both natives and settlers. The advent of Col. Arthur in 1824 as Lieut.-Governor resulted in new efforts being made to improve the situation. Col. Arthur in his outward despatches reports at length on his measures to the Secretary of State for the Colonies, as the position was somewhat of an embarrassment to the Minister in London.

Arthur proposed to offer rewards for those who were able to persuade natives, by peaceful means, to come in and place themselves under the protection of the Government. The only real success achieved was that of Mr. John Batman. Similar attempts with larger parties only increased the tension.

Proclamations confining specific tribes to certain localities (with seasonal access to the coast) also with pictorial ones which portrayed the nature of our justice with equal punishment to both races for killing the other, were possibly not in the least intelligible to the aboriginals. Indeed it could hardly have been expected that they would have been of any practical use. The settlers turned to friendly natives, who, able to move swiftly through the bush, were offered rewards of land grants, if they would bring in natives peacefully to a Mission Station established on Bruni Island. As stated, only the party of John Batman met with any success; and meanwhile throughout the Island serious incidents occurred with increasing frequency. The killing and driving off of stock and sheep, burning of barns, outbuildings and homesteads and the wounding or murdering of lonely shepherds, women and children were widespread through the island. The natives were of course extremely mobile and usually escaped without interference and moved off to strike again probably many miles away on the other parts of the Island.

Reprisals became more savage and Arthur, realising that the trial of his form of peaceful conciliation of the aboriginals had failed, turned to a more comprehensive and national effort. This operation has become known as the Black Line or Black War. The method employed was to group selected bodies of soldiers and colonists at strategic points under local settlers of influence, who had qualities of leadership and a knowledge of the country to be worked over. At a given time, these commandos were to advance with close co-ordination so that the natives would be driven in front of them and eventually herded on to Forrestiers Peninsula, the narrow isthmus of which could be guarded, and the natives trapped to exist on the game and fish to be found in the large areas of country of the two Peninsulas.

Martial law was proclaimed on November 1st, 1830, and the co-ordinated movement of all the parties commenced on October 7th and continued to November 26th, when it was found that one native man and one boy had been captured and one volunteer wounded.

To effect this result, some £35,000 had been expended with nearly 3,000 military and constabulary engaged, 1,500 of whom were from Hobart Town and 500 from Launceston.

Stalemate had been reached, but help was to come from an unexpected quarter.

George Augustus Robinson a builder at Hobart had gained personal experience of the aborigines as superintendent of a Government Mission for the natives, at Mission Bay, N. Bruni Island. Robinson believed he would be able to persuade the natives to come in if he went with friendly natives and made contact with them in the bush and put this proposition to Col. Arthur. Arthur agreed to the proposal and granted supplies and permission for a small party to set out and make the attempt. Bruni Island was regarded as too close to Hobart Town so instead of the shelter at Mission Bay, Swan and Gun-Carriage Islands, in Bass Strait adjacent to Flinders Island were selected as suitable for the first 56 natives brought in as a result of Robinson's efforts. The quarters at these small islands were very cramped and unsuitable and as more aboriginals gave themselves up a move was made to the large Flinders Island to a site just inland from the west coast a few miles above the township of Whitemark. This station was called Wybalenna. To this area between 1834 and 1838 came 203 natives, actually almost all the survivors of their race then at large in Tasmania.

Every effort was made to preserve and look after this unfortunate remnant, but our civilisation—with clothes, unsuitable food, a stationary life and no suitable occupation for either woman or men proved fatal to them. The white man's diseases, and an overwhelming nostalgia for their old home, which could be actually seen from the mountains behind the station, brought about a terrible decline in their numbers.

Only 123 remained at the end of 1838 and it was decided to bring the survivors back to Tasmania and the move took place to the old Probationary station at Oyster Cove. This did not arrest the decline, as alcohol was now to be had and in 1854 there were only 16 survivors and by 1869 only four elderly women. The end came when the last, Truganini then aged approximately 70 years, died on May 10th, 1876.

Now all that remains are the skeletal collections and their stone implements which, with the spring ploughing, are still to be found. The largest collection numerically of Crania and Bones is now that of the Tasmanian Museum, and it is fortunate indeed that Professor Abbie, at the invitation of the Trustees has furnished this detailed list of the material in their keeping and which are described in the following article.

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AN EXAMINATION OF THE W. L. CROWTHER COLLECTION OF SKELETAL MATERIAL

By

A. A. ABBIE

THE W. L. CROWTHER COLLECTION OF SKELETAL MATERIAL

FOREWORD

I examined this collection at the invitation of Dr. W. Bryden, Director of the Tasmanian Museum and Art Gallery, during the week 8th-15th February, 1963.

A preliminary survey disclosed that it would not be possible for any one person to do justice to the collection in a week—an adequate description would require at least six months. Some selection was necessary, therefore, and was exercised on the following basis:—

1. All material of European origin or suspected of being such was set aside as requiring no further attention.
2. Of the remaining material of suspected non-European origin the crania were considered most important so, while the post-cranial skeleton under this heading is described, the description is relatively sketchy, but is elaborated by notes from time to time. Some of these bones were measured.
3. So far as the cranial material goes, all the skulls that had already been described by Wunderly (1939) were left out and attention was paid only to those hitherto undescribed. I appreciate that my descriptions of these skulls are quite inadequate because, under pressure of time, I concentrated on the features most likely to be of value for ethnic diagnosis. To assist in this I have appended tables of the most important measurements of the skulls and of such mandibles as had survived.

I must express my appreciation of the generous assistance I received from Dr. Bryden and his staff and from the Librarian of the Royal Society of Tasmania during my most pleasant stay in Hobart. In particular, I am deeply grateful to Mrs. J. Greenhill who acted as my amanuensis most unselfishly; without her help I should not have been able to get through what I have done in the time.

A. A. Abbie.

The following were considered to be of probable European origin and are not described in detail:—

Cranial fragments

10 AG Mandible from a child aged 10-12 years.
11 AG Mandible, adult.
12 AG Mandible, adult.
15 AG Right parietal bone.
16 AG Calvaria.
17 AG Calvaria with some dried soft tissues adherent.
19 AG Sphenoid bone with no identifiable ethnic characters.
20 AG Right maxilla from a child aged 10-12 years.

General skeleton

1 right scapula with clavicle, humerus and ulna.
1 right clavicle attached to proximal end of humerus.
2 left scapulae.
1 right humerus.
Distal quarter of right humerus with radius and ulna attached.
1 left humerus sawn through at junction of middle and proximal thirds.
1 right radius.
1 left radius.
2 left ulnae.
Articulated left hand.
Partly dissected hand.
2 metacarpal bones.
2 lower ribs.
1 male sacrum of six segments.
1 eroded sacrum of four segments.
2 right hip bones.
2 right femora, one with malunited fracture in proximal third.
Sectioned proximal third of a right femur.
1 right tibia.
1 left tibia.
2 right fibulae.
Posterior half of a right foot.
1 each left talus, navicular and cuboid bones.
1 right navicular.
6 metatarsal bones.
Articulated right and left feet.

Immature skeleton, apparently European.

1 mid-cervical vertebra.
1 left scapula.
1 each right humerus, radius and ulna.
1 sacrum of four loosely articulated segments.
2 immature hip bones from separate individuals, both male.
2 femora, right and left.
2 tibiae, right and left.
1 fibula.
Detached proximal epiphysis of left humerus.
Detached distal epiphysis of left femur.
Detached proximal epiphysis of left tibia.

Box labelled—" Tasmanian Fragments I "

Contained:—

1 mandible, probably adult Tasmanian male, several teeth missing. Now numbered 21 AG and considered separately below.
1 third right lower molar tooth, not from above mandible.
Five fragments of a plaster cast of the upper and lower jaws.
1 set of 7 cervical vertebrae plus the first thoracic, matted in peaty fibres.
2 sets of the upper 5 cervical vertebrae, matted in peaty fibres.
1 set of 4-5 upper cervical vertebrae, matted in peaty fibres.
2 sets of the upper 4 cervical vertebrae (one set very fragile), matted in peaty fibres.
(N.B.—In all these sets of cervical vertebrae the atlas is displaced and rotated as though the head had been forcibly rotated before burial.)
1 separate atlas vertebra.

Box labelled " Tasmanian Remains Sanford I "

In this were:—

2 small boxes, one containing 5 cervical vertebrae, more or less damaged; and the other had:—
2 incomplete clavicles, presumably a pair.
A small portion of a right scapula.
A number of unidentifiable bony fragments.
1 worked stone.
Several pieces of charcoal.
1 partly fossilized Gasteropod operculum.

Box labelled " Tasmanian Remains Sanford II "

In this were—A cigar box containing:—

Several broken bone fragments one of which appeared to be portion of a metacarpal and and another a phalanx.
Several pieces of charcoal.
Several pieces of stone (? worked).

A California chocolate box containing:—

A small cranial fragment.
Proximal third of a left humerus, head present but broken off.
Distal portion of a left femur.
Left patella.
2 other bony fragments.
Fragment of rock.

POST-CRANIAL TASMANIAN SKELETAL MATERIAL

This was excavated by Dr. Crowther at Oyster Cove. Most of the bones are discoloured black, a number are fragmentary or badly eroded, and many were embedded in a peaty mass of rootlets. They were housed in two large modern cases.

The bones examined were:—

A fragment of a right scapula.

3 right humeri, mostly badly eroded, length range 303-324 mm., and portions of 4 others.
2 left humeri, more or less complete, length range 286-303 mm., and 2 incomplete, 1 detached humeral head.
3 right radii, 2 lacking heads.
1 right radius and ulna, adherent at proximal ends, distal end of ulnar styloid process missing. Radial length range 228-232 mm.
2 right ulnae, 1 fractured, 233 mm.
3 left ulnae, 1 missing styloid process, length range 231-234 mm.

(N.B.—The ulnae were very long and slender and showed a tendency to curvature of the shaft.)

1 complete sternum, all joints fused.
3 rib fragments.
2 separate sets of 3 lumbar vertebrae, each embedded in a peaty mass of rootlets.
2 complete sacra: one 100 mm. broad by 96 mm. long, the other 97 x 92 mm.

A fragment comprising only the upper two segments of a sacrum together with a partly attached 5th lumbar vertebra.

3 almost complete right hip bones, one male the other two almost certainly female. The male hip bone fits the largest femur listed below. Portions of 2 more right hip bones, sex doubtful.

Portions of 6 left hip bones, five almost certainly male, one almost certainly female. Fragments of 3 others.

(N.B.—In most peoples the shape and size of the greater sciatic notch is one of the most valuable guides in sexing hip bones. This was not the case with these Tasmanian hip bones in which the notch did not show much difference in the two sexes. Consequently, the sexing was based mainly upon the size of the acetabulum which is both relatively and absolutely larger in the male.)

3 right femora more or less complete of gross lengths 482 mm., 438 mm., 425 mm. Shortest femur had displaced patella stuck to its side. 4 incomplete right femora.
6 left femora more or less complete. Those matching the three right femora measured respectively 480 mm., 436 mm., 420 mm.
1 left femur with displaced patella attached and 3 damaged femora.
5 right tibiae, more or less complete. The 3 matching the right femora measured respectively 405 mm., 358 mm., 351 mm.

There were also 4 fragmentary right tibiae.

3 left tibiae reasonably complete, 4 more or less severely damaged.
2 right fibulae, damaged, one very grossly flattened and bent laterally and forwards in the proximal third.
2 left fibulae more or less complete, 1 incomplete apparently matched bent right fibula. Longest left fibula measured 382 mm. and belonged to longest left tibia.

(N.B.—The lengths of the three right femora exceed slightly the lengths of the corresponding left femora. Those measured were all from males and even allowing only a modest 24% for their proportion of total stature they work out at statures of approximately 2000 mm., 1825 mm., and 1771., respectively—say, 6 ft. 6 in., 6 ft. 1in., and 5 ft. 11 in. This does not support recent views that the Tasmanians were diminutive. The tibiofemoral indices work out at 84.0, 81.7 and 82.5 respectively. There is nothing remarkable in these indices.)

1 right calcaneum.
1 left talus, calcaneum, navicular, cuboid and 3 cuneform bones all loosely held together by a peaty mass of rootlets.

There were also several large peaty masses many of which showed evidence of containing bones. One of the largest was opened and disclosed portion of a right hip bone attached to a right femur and associated with a right tibia. The others were left untouched.

CRANIAL COLLECTION

Note.—All the unnumbered crania and cranial fragments were numbered for identification in a separate series:—" W.L.C. 1 AG, 2 AG . . . . &c."

1. Isolated Mandibles

WLC 9 AG

This is from an adult female of small dimensions; there is no reason to doubt that she was a Tasmanian. All the teeth have been lost except the two third molars: These are only slightly worn (approaching Broca grade 2) and indicate that the owner, although adult, was still quite young. In general the bone is slender and delicate but it is supported on the inner side by a thick bony torus which is continuous with the mlyohyoid line below and runs back and up to form a strong buttress on the medial side of the coronoid process. The usual bony markings on the body are well defined, the chin is not prominent. The mandibular foramen runs forwards rather than downwards and lacks a lingula. The ramus is very quadrangular (a female character), the angles are slightly everted and the masseteric attachment is well marked. The condyles are orientated almost exactly transversely and are slightly " mushroomed," a common accompaniment to a coarse diet.

WLC 21 AG

Several teeth missing, similar generally to 9 AG but larger and more robust. Male, probably Tasmanian.

The measurements of the mandibles are given at the end. (Table II).

2. Other Cranial Fragments

WLC 13 AG

Right temporal bone, evidently from a small adult skull. Very small mastoid process and a small broken styloid process. There is a foramen

(of Huschke) in the tympanic bone on the posterior wall of the mandibular fossa. Although adult the bone has disarticulated cleanly all round so the owner was relatively young. I suggest a young Tasmanian female.

WLC 14 AG

Right temporal bone quite similar to above but smaller overall. Mastoid and styloid processes very small. No foramen of Huschke. Also, probably, a young Tasmanian female.

WLC 18 AG

Lower left posterior portion of skull. Inscription inside not decipherable.

There is an ante-mortem perforation in the floor of the posterior cranial fossa. Mastoid process relatively small. Styloid process apparently large but broken off about 7 mm. from its base. Foramen lacerum small. Superior nuchal line is well developed with a prominent external occipital protuberance. The lateral quarter of the lambdoidal suture is obliterated. All this suggests that the fragment came from the skull of an adult male getting on in years and probably not European; therefore, most likely to be Tasmanian.

3. Crania

Note:—

Berry and Robertson (1910) depicted the following numbered skulls as belonging to the "Dr. E. L. Crowther" collection: (Crowther numbers in brackets): 39 (1), 40 (3), 41 (4), 42 (5), 43 6), 44 (7), 45 (8), 46 (9), 47 (10), 48 (11), 49 (12), 50 (13). Of these I could find only 41 (4), 42 (5), 43 (6), 45 (8), 46 (9), 49 (12), 50 (13); the fate of 39 (1), 40 (3), 44 (7), 47 (10) and 48 (11) can only be conjectured. Berry and Robertson accepted all of these as Tasmanian but their description of the skulls is extremely sketchy while their other publications (1909 a, 1909 b) are little more than accounts of how the skulls were discovered.

Wunderly (1939) rejected 49 (12) as being Australian. He described as Tasmanian 40 (3), 42 (5), 43 (6), 44 (1 !), 45 (8), 46 (9), 50 (13), 57 (18), 86 (14) and 89 (17). Evidently, the Crowther collection had already become depleted before Wunderly examined it; also, it seems that 44 (1) should have been 44 (7). Of the collection in the present survey, in addition to 49 (12), Wunderly rejected as Australian 85 (15), 88 (16) and 112 (19).

The crania that Wunderly **described** are omitted from further consideration here. Those remaining of the collection Berry and Robertson **depicted,** namely, 41 (4), 47 (10), 48 (11) and 49 (12), are considered in as much detail as time permitted. Other numbered skulls, rejected by Wunderly, namely, 87 (15), 88 (16) and 112 (19) are also described here. There were, in addition, eight more skulls unnumbered and these, as already noted, are identified as a separate series: "WLC AG 1-8". The total of crania to be described thus comes to fifteen. In what follows a general description of each skull is given first and the measurements are all consolidated in a single table at the end (Table I).

Tasman Series 41, B & R 41, WLC 4

This skull is discoloured, apparently from fire as a number of the sutures are "sprung". There is a good deal of peaty rootlet material adherent to the base of the skull and in the various cavities. The nasal bones are missing, left inferior orbital margin damaged, both zygomatic arches broken, the anterior part of the palate bearing canine and incisor teeth is missing, posterior part of palate damaged. There is no mandible (N.B.—Berry and Robertson depict a mandible—41 E; their other illustrations show intact nasal bones and a more complete palate and more teeth and apparently intact zygomatic arches.) All the molar teeth had erupted fully but the second left is missing and the first left is broken. These teeth are fairly worn and there is a good deal of interproximal attrition; nevertheless, the generally open condition of the sutures suggests that the owner was relatively young. (In Australian aborigines teeth wear faster in women than in men and the same may well hold for Tasmanians.) The nasal extremity of the metopic suture is unfused for about 10 mm. The mastoid processes are very small. There are several Wormian bones related to the sutures between the occipital and parietal bones. In particular, there is a triangular cluster of four Wormian bones in the region around the lambda. These could be considered interparietal bones. Berry and Roberston put the lambda itself between the intermediate and superior of these bones. In this I concur; I also concur in their view that the skull is that of a female Tasmanian.

Diagnosis; Female, Tasmanian, 25-30 years of age.

Tasman Series 47, B & R 47, WLC 10

The whole of the facial part of this skull and most of the base are missing. Part of the skull is blackened as though from fire and there is a considerable mat of rootlets within the cranial cavity. The coronal sutures are beginning to close at their temporal ends, the sagittal and lamboidal sutures are fully open. The superior nuchal line is marked. Enough of the left temporal bone remains to show the external auditory meatus and a very small mastoid process. The glabella is probably just missing so that the measurement given for maximum length is a little doubtful. I agree with Berry and Robertson that this is from a female and probably Tasmanian. From the condition of the sutures I consider that she was relatively young.

Diagnosis: Female, Tasmanian, about 30 years of age.

Tasman Series 48, B & R 48, WLC 11

This small skull is very broken up. There are some peaty fibrous fragments associated with it and what appears to be the charred, dessicated and shrunken remains of the right half of the brain—very much smaller than the cranial cavity from which it presumably came. Most of the left frontoparietal region is missing. The right maxilla is wholly detached from the base of the skull but can be restored. The right mastoid process is small. Most of the right half of the mandible is present, the ramus is quadrangular. In the maxilla the

second permanent molar tooth is almost fully erupted, the third is about to break through. In the mandible the second permanent molar is fully erupted and the third has just cleared the alveolar margin. These findings are at some variance with the condition illustrated by Berry and Robertson in 48D. They put the age at 20-40 years which is certainly too high; 14-16 years would be nearer the mark. They also suggest that this may be from a half-caste but I can find no support for this.

Diagnosis: Female, Tasmanian, 14-16 years of age.

Tasman Series 49, B & R 49, WLC 12

This specimen includes the mandible but this is not figured by Berry and Robertson. In general, when viewed from above, the skull is relatively narrower than the Tasmanian because of the absence of any prominent parietal bossing. It is evidently from a young female, being relatively small and having all the normal cranial joints, including the spheno-basilar, quite open. The pterion is H-shaped on both sides. The mastoid processes are relatively small, the styloid processes are broken off. The foramen lacerum is small. There are small but definite brow ridges and the superior nuchal line is well defined. The interior narial margin is rounded with a prominent nasal spine. The spheno-maxillary fissure is relatively wide. There is a trace of a pre-pterygoid process. The palate is broadly paraboloid. The third molars were partially erupted but that on the left is lost; missing in addition since Berry and Robertson figured this skull in 1910 are both left incisors, left canine and left second premolar. All the other teeth are present including a right lateral incisor that is displaced palatally between the two adjoining teeth. The surviving teeth show little wear.

The mandible is small and light, there is no marked mental prominence, the body is slender, the mental foramina lie between second premolar and first molar teeth and run forwards, the angles are inverted. The ramus is quadrangular and slopes steeply back. The coronoid process is slender, the condyles are directed slightly backwards of the transverse plane and the medial side of the left condyle is broken off. The lateral pterygoid fossa is well marked. The mandibular foramen runs more forwards than downwards; a well developed torus runs up from the mylo-hyoid line to buttress the inner side of the coronoid process. Genial tubercles are not evident. The digastric and submandibular fossae are well marked but not the sublingual fossa. The third molars are unerupted; the left canine, both right incisors and the right first premolar are missing; the surviving teeth are only slightly worn.

Berry and Robertson were, apparently, happy to include this skull as a Tasmanian but Wunderly considered it Australian. On the whole the evidence supports Wunderly.

Diagnosis: Female, probably Australian, aged 16-18 years.

Tasman Series 87, WLC 15

No mandible. There has been some restoration, particularly in the left temporal region. This is evidently from a female approaching middle age. Most of the sutures show signs of closure and those forming the pterion are obliterated. The left zygomatic arch is broken and there are a number of other defects including a large hole in the floor of the left posterior cranial fossa. In the region of the left stephanion there is an irregular eroded lesion, about 26 mm. long, which opens into the cranial cavity behind the coronal suture. The erosion appears to be due to an infective process, e.g., osteomyelitis. Neither brow ridges nor superior nuchal lines are marked. The parietal regions are well rounded. The right mastoid process is small, the left is missing; the right styloid process is strongly developed, the left is broken off. There is a small foramen of Huschke in the left tympanic bone. The foramen lacerum is quite large. The posterior wall of the right maxilla is damaged. Most of the right nasal bone is missing. The lower narial margin is sharp, the spine is prominent. The palate is almost quadrangular; the third right molar and all four incisor teeth are missing. The third left molar is erupted but not much worn, the other remaining teeth are moderately worn.

Wunderly considered this skull Australian but to my mind the rounded parietal regions and particularly the sharp lower narial margin argue against an Australian origin.

Diagnosis: Female, could be Tasmanian x European cross, approaching middle age.

Tasman Series 88, WLC 16

No mandible. This skull is from a young female.

The spheno-basilar joint is open as are all the normal cranial sutures.

In norma verticalis the skull contour is almost pentagonoid. There is a slight brow ridge and the superior nuchal lines are just defined. Pterion on both sides is H-shaped. The mastoid processes are small, the styloid processes are broken off. The foramen lacerum is very small, the sphenomaxillary fissure is wide ;there is no pre-pterygoid process. The lower narial margin is rounded, with a prominent spine. The palate is a wide paraboloid. The third molar teeth are unerupted and of the remainder only the first and second molars on each side survive—the first shows some wear. In Table II the palatal length given is to the posterior border of second molars as the third molars are still high up in the maxillae.

Wunderly considered this skull Australian but I must point out that the ethnic attribution of any female skull is always a difficult matter because of the relatively poorer differentiation as compared with the male. In this present instance the difficulty is increased by the lack of maturity of the subject. To my mind there is no single feature or group of features that disqualifies this skull from Tasmanian attribution.

Diagnosis: Female, probably Tasmanian, aged 13-15 years.

Tasman Series 112, WLC 19

This is a large heavy skull, obviously from a male. The right zygomatic arch is missing, the posterior wall of the right maxilla is broken, there is a large defect in the right parieto-temporal region, the left zygoma and part of the left maxilla are broken off and some bones are held together with wire. The skull is long and narrow, most sutures are virtually closed. the brow ridges are very large, the forehead slopes steeply, the superior nuchal lines are strongly defined, the external occipital protuberance is represented by an area of bone projecting downwards and forwards. The mastoid processes are moderately large, the styloid processes are broken but were evidently small, the foramen lacerum is small. There is a well developed pre-pterygoid process. The lower narial margin is guttered, the anterior nasal spine is prominent. The palate is a broad massive parabola showing considerable ridging. The only surviving teeth are the right first molar, the right first premolar, the right canine and the root of the left second premolar. I concur in Wunderly's opinion that this is an Australian skull.

Diagnosis: Male, Australian, past middle age.

WLC 1 AG

This skull is large and well rounded. The calvaria has been sawn off but is present and the cranial cavity is undamaged. The coronal suture is approaching obliteration throughout, the sagittal suture has virtually disappeared, the lambdoidal and temporo-parietal sutures are readily apparent. The pterion is almost X-shaped on the left side but more H-shaped on the right. Brow ridges are scarcely developed, the superior nuchal lines are poorly marked. The mastoid processes are large and it is evident that the styloid processes were also large during life. The mandibular fossae show bony deposits that make them shallower than normal (the mandibular condyles are correspondingly mushroomed). The spheno-maxillary fissures are widely open. The nasal bridge is relatively high, the lower narial margin is rounded with a prominent spine. The palate is paraboloid. The third molars are unerupted: of the remainder those that survive are; first and second right molars, large, and much worn; all four premolars showing a moderate amount of wear; the left canine, large, moderately worn with massive root reaching up almost to the narial margin.

The mandible is of moderate size with a well developed mental protuberance although the body is shallow in the posterior molar region. The mental foramen is opposite the second premolar tooth and runs forwards into the bone. The angle is quite rough at the masseteric insertion and the gonion is everted. The ramus joins the body at a fairly acute angle. The coronoid process is relatively thin. The heads of the condyles are directed silghtly backwards of the transverse plane and show distinct flattening or mushrooming. On the medial side a well developed torus runs up from the mylohyoid line to buttress the coronoid process. The mandibular foramen runs more forwards than downwards and is protected by a fair-sized lingula. The superior genial tubercles are fused, the inferior separate. The digastric and submandibular fossae are well marked, but not the fossa for the sublingual gland. The third left molar is fully erupted and moderately worn; the second left molar is missing, the first left molar is very large and moderately worn. Both left premolars are present, moderately worn. The second and third right molars were lost during life and the alveolar margin is resorbed. The first right molar resembles the left but has a cavity at its distal border which appears to have been the source of a periapical abcess that has perforated the buccal aspect of the alveolar bone. The second right premolar has broken off short, the first resembles the left. The right canine is large, moderately worn; the left is missing. The incisors have been lost and from the socket space available it looks as though there were only 2 incisors all told during life.

Diagnosis: Male, Tasmanian, at about middle life.

WLC 2 AG

No mandible. Very well marked skull of an adult male, comparable in size to 1 AG. Coronal suture shows beginning obliteration in temporal fossae and at the bregma, remaining sutures still well open. Left pterion is H-shaped, right less so. Brow ridges are small but well defined, superior nuchal lines only moderately prominent, external occipital protuberance hooked downwards. Mastoid processes large, styloid processes broken off. Foramen lacerum is small. Very well developed pre-pterygoid process, very open spheno-maxillary fissure. Lower narial margin is rounded, anterior nasal spine bifid. Palate is paraboloid. Both third molars fully erupted and well developed; both second molars present show very little wear; both first molars missing. Both right pre-molars are carious and worn down considerably; second left pre-molar missing, first left well developed and moderately worn. Left canine is present, of moderate size and showing only slight wear; right canine and all four incisors missing.

Diagnosis: Male, Tasmanian, aged 30-40 years.

WLC 3 AG

No mandible. Well developed adult male. Most sutures approaching obliteration but still recognisable. Obelion is well marked. Pterion on both sides H-shaped. Brow ridges virtually absent except medially; nasal end of metopic suture persists for about 10 mm. Superior nuchal lines well marked; external occipital protuberance hooks downwards. Mastoid processes large; styloid processes broken off but evidently small. Foramen lacerum small. Well deveolped pre-pterygoid process. Spheno-maxillary fissure relatively narrow. The mandibular fossae both show bony deposition and shallowing. The lower narial margin is rounded, with a prominent anterior nasal spine. The palate is a broad paraboloid. The only surviving teeth are the right second premolar, right second molar, left third molar (all showing very little wear) and the roots of the first molar.

The forehead is rather more sloping than in most Tasmanian skulls but there are the characteristic parietal bosses.

Diagnosis: Male, Tasmanian, about middle age.

Note.—In these three skulls 1 AG, 2 AG and 3 AG, the amount of wearing of the teeth is relatively less than one would expect from the age indications of the state of closure of the sutures. It has been shown that the age of suture closure is not a reliable guide to age; nevertheless, there is some correlation and experience with skulls of other peoples leads one to expect a greater degree of dental wear than these skulls in fact show. This suggests that their owners lived mainly on a European diet, not the coarse native diet, a suggestion supported by the dental caries in 2 AG.

WLC 4AG

Large, well marked skull, evidently from an adult male. The coronal and sagittal sutures are beginning to fuse around the bregma, all otherwise are well open. There is a moderate-sized interparietal bone at the lambda. Pterion is H-shaped on both sides. The forehead has a moderate slope and the frontal bone shows a rough antemortem lesion, about 70 mm. x 30 mm. which is pitted in parts and is probably the result of old injury and/or disease. The brow ridges and superior nuchal lines are very well developed, the external occipital protuberance is not prominent. The mastoid processes are well developed; the left styloid process is large, the right broken off. There is a large prepterygoid process. The spheno-maxillary fissure is wide. The lower narial margin is rounded but the spine is not particularly prominent. The palate is a broad paraboloid with well-marked palatal tori posteriorly. the only missing teeth are the two upper central incisors (lost post mortem), the first right premolar and the right third molar; the second right molar is broken off at the root. The surviving teeth are large, very little worn and show no evidence of caries. The surviving third molar is only slightly smaller than the second.

The mandible has a relatively strong body, the body height almost equalling the symphyseal height. The mental foramen is at the level of the second premolar tooth and runs downwards and forwards. The angle is strongly everted on each side with well marked muscle attachments. The condylar heads show no sign of flattening; they are directed slightly backwards of the transverse plane. The coronoid process is buttressed on its medial side by a well-marked torus. The mandibular foramen runs downwards and forwards and has no lingula. The superior genial tubercles are separate, the inferior fused. The digastric, sublingual and submandibular fossae are distinctly marked; a small bony ridge runs horizontally above the digastric fossae. Only the molar teeth survive—they show slight wear.

Diagnosis: Male, Australian, age 25-30 years.

WLC 5 AG

No mandible, Adult male.

Most of the left side of the face and a good deal of the base are missing. The right maxilla is broken in places. The frontal bone shows marked signs of disease or damage over a wide area. Most sutures are obliterated but the left pterion could be discerned as H-shaped. Brow ridges are well marked and the superior nuchal line forms a distinct crest in its middle third. Right mastoid process is broken off, the left is of moderate size; both styloid processes are missing. The pre-pterygoid process is well marked, the spheno-maxillary fissure is of moderate width. The lower narial margin is rounded, the anterior nasal spine prominent. Most or all the upper teeth had been lost during life.

Diagnosis: Male, Australian, age fairly advanced.

WLC 6 AG

No mandible. Inscribed " Solomon Islander ".

Relatively small, smooth skull, clearly from a female.

Sagittal suture fairly closed, right coronal suture closing in the temporal fossa, left open; right pterion almost H-shaped, left stellate. Lambdoidal suture closing. Very little brow ridge, small superior nuchal line. Mastoid process of medium size; left styloid process well developed, right broken off. Foramen lacerum very small. Pre-pterygoid process well developed; spheno-maxillary fissure wide. The lower narial margin is rounded. The palate is a broad paraboloid. All teeth had erupted but the only survivors are right first and second molars and left second and third molars, the third almost as large as the second . All these teeth show a moderate amount of wear.

Diagnosis: Female, Melanesian, approaching middle age.

WLC 7 AG

No mandible. Also inscribed " Solomon Islander ".

Relatively small and smooth and obviously female.

Both zygomatic arches broken off. Lateral walls of both orbits broken. Sphenoid bone largely missing. Most of the coronal, all the sagittal and the middle third of the lambdoidal suture are fused. Pterion stellate on the left, missing on the right. Brow ridges and superior nuchal line small. Mastoid processes fairly small, styloid processes broken off. No pre-ptyerygoid process; spheno-maxillary fissure open. Lower narial margin rounded, spine prominent. Palate relatively broad paraboloid. Third molars unerupted, all other teeth missing. Upper left central incisor extracted during life and socket resorbed.

Diagnosis: Female, Melanesian, past middle age.

WLC 8 AG

This is almost certainly a European male and is not considered further here. The measurements are given in Table I.

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TABLE I.

No.	Sex	L.	B.	H.	Min. Front D.	Total Facial H.	Upper Facial H.	Bizyg. D.	Bigon. D.	Orb. H.	Orb. B.	Nas. H.	Nas. B.	Pal. L.	Pal. B.	Facial Angle	Remarks
Tas. 41 WLC 4	F.	178	127	104	89	..	..	..	..	29	34	..	..	..	..	..	Tasmanian
Tas. 47 WLC 10	F.	161	132	103	..	..	..	..	..	..	..	..	..	..	..	..	Tasmanian
Tas. 48 WLC 11	F.	145	116	88	..	..	..	..	..	..	..	..	..	..	..	..	Tasmanian
Tas. 49 WLC 12	F.	164	121	100	84	94	57	113	78	33	37	41	25	51	33	79°	Probably Australian
Tas. 87 WLC 15	F.	178	129	99	93	..	58	..	..	32	39	41	26	44	35	82°	European × Tasmanian Cross
Tas. 88 WLC 16	F.	177	135	104	96	..	61	122	..	32	42	44	26	46	36	80°	Tasmanian
Tas. 112 WLC 19	M.	197	126	117	104	..	69	..	..	31	44	45	27	66	43	74°	Australian
WLC 1AG	M.	184	138	113	100	122	73	131	99	34	41	50	26	55	35	82°	Tasmanian
WLC 2AG	M.	184	138	114	96	..	68	131	..	31	39	50	29	55	39	73°	Tasmanian
WLC 3AG	M.	177	140	114	103	..	78	128	..	32	41	55	27	53	42	84°	Tasmanian
WLC 4AG	M.	198	140	111	99	115	69	140	119	33	36	48	28	52	43	87°	Australian
WLC 5AG	M.	181	130	121	87	..	61	..	..	33	42	50	23	..	..	84°	Australian
WLC 6AG	F.	181	123	114	90	..	63	122	..	30	40	44	24	47	38	77°	Melanesian
WLC 7AG	F.	176	128	107	91	..	62	..	..	33	40	48	26	50	33	79°	Melanesian
WLC 8AG	M.	194	147	114	103	..	74	..	..	36	38	51	25	51	33	89°	Probably European

TABLE II.

MANDIBLES

Number	Sex	Bicond. B.	Bigon. B.	Ramus L.	Ramus Min. B.	Ramus Max. B.	Symph. H.	Body H.	*Max. Thick-- ness	Remarks
Tas. 49 WLC 12	F.	99	80	42	30	33	24	22	14	Prob. Australian
WLC 1AG	M.	116	101	67	36	41	27	14	14	Tasmanian
WLC 4AG	M.	120	110	71	35	46	32	31	17	Australian
WLC 9AG	F.	118	86	56	34	39	26	22	14	Tasmanian
WLC 21AG	M.	123	108	70	34	45	31	27	15	Tasmanian

*At level of second molar tooth.

THE FACTOR OF TIMING IN THE EMERGENCE OF DISTINCTIVELY HUMAN CHARACTERS

by

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(With six text figures)

(*Communicated by Dr. W. Bryden.*)

INTRODUCTION

Any assessment of Darwin's *Origin of Species* must take into account evidence from the whole world of biology, and that will necessarily come mainly from non-human sources. Nevertheless, we are all human and at some stage inevitably comes the query: "how does this affect me? Darwin's (1859) modest hint that "Light will be shed upon the origin of man and his history" set the pattern from the outset. However detached we feel ourselves to be the personal implications of evolutionary theory inevitably inject an anthropocentric bias into our thinging, and that is my excuse for talking about man tonight.

Darwin's supporters followed up his hint in the then fashionable direction of seeking forms intermediate between man and the other primates. Every ancient skull was closely scrutinized for such features as smaller brain, bigger jaws, large brow ridges, retreating forehead—anything that might link it a little closer to the ape. The greater the antiquity the better, of course; but any modern-looking human skull in an ancient stratum was almost automatically rejected as a recent intrusion. Those people knew what to look for, and they found it.

Not all were indifferent to objective appraisement of the evidence, however. So long ago as 1863 T. H. Huxley (Huxley, 1894) pointed out that the Neanderthal skull—the then prize "missing link"—showed no features that could not be matched from modern skulls, citing the Australian Aborigine among others. His warning was either ignored or it was misrepresented as a claim that the Aborigine was a surviving representative of Neanderthal Man. In any case, subsequent discoveries of *Pithecanthropus, Sinanthropus et omnia sic alia* seemed to dispose effectively of such academic quibbles.

Thus a nicely graded series from *Pithecanthropus* up to modern man was set up on purely morphological grounds, although some serious discrepancies existed (Abbie, 1952a). But when it came to arranging these forms in a convincing chronological order the system foundered badly. Most inconsiderately, the proven oldest skull is none of these—it is the Swanscombe skull, which cannot be distinguished from modern skulls (Le Gros Clark 1938). *Pithecanthropus* and *Sinanthropus* were no older than Swanscombe and might be much younger; Neanderthal Man appeared only yesterday. This inconvenience was countered by the claim that *Pithecanthropus* and Co. were simply specialized terminal offshoots of the common evolutionary line leading to man. That could be so but supporting evidence has yet to be produced: the onus of proof clearly falls upon whose views require this argument.

Attention has lately been attracted to the Miocene apes of East Africa and the *Australopithecinae* of South Africa as an evolutionary line possibly ancestral to man (Le Gros Clark and Leakey, 1951). The possibility cannot be denied (see, e.g., Broom, 1946; Dart, 1940; Le Gros Clark, 1950a) but while the *Australopithecine* teeth and posture seem to foreshadow the human the brain is still within the range of the ape (Robinson, 1960). And again, there are chronological difficulties.

On every present indication there has been only one kind of man who has always been much as we know him today in all his variety. And he seems to have appeared fairly suddenly between the beginning and middle of the Pleistocene—i.e., from 1,000,000 to 500,000 years ago (Le Gros Clark, 1950b).

If we provisionally dismiss from our minds all the traditional views on human evolution by gradual modification the problem can be approached from a completely different aspect. In particular, we shall be free to ask what known biological factors could have produced the human species fairly suddenly from some other animal: preferably, but not necessarily, from some other primate.

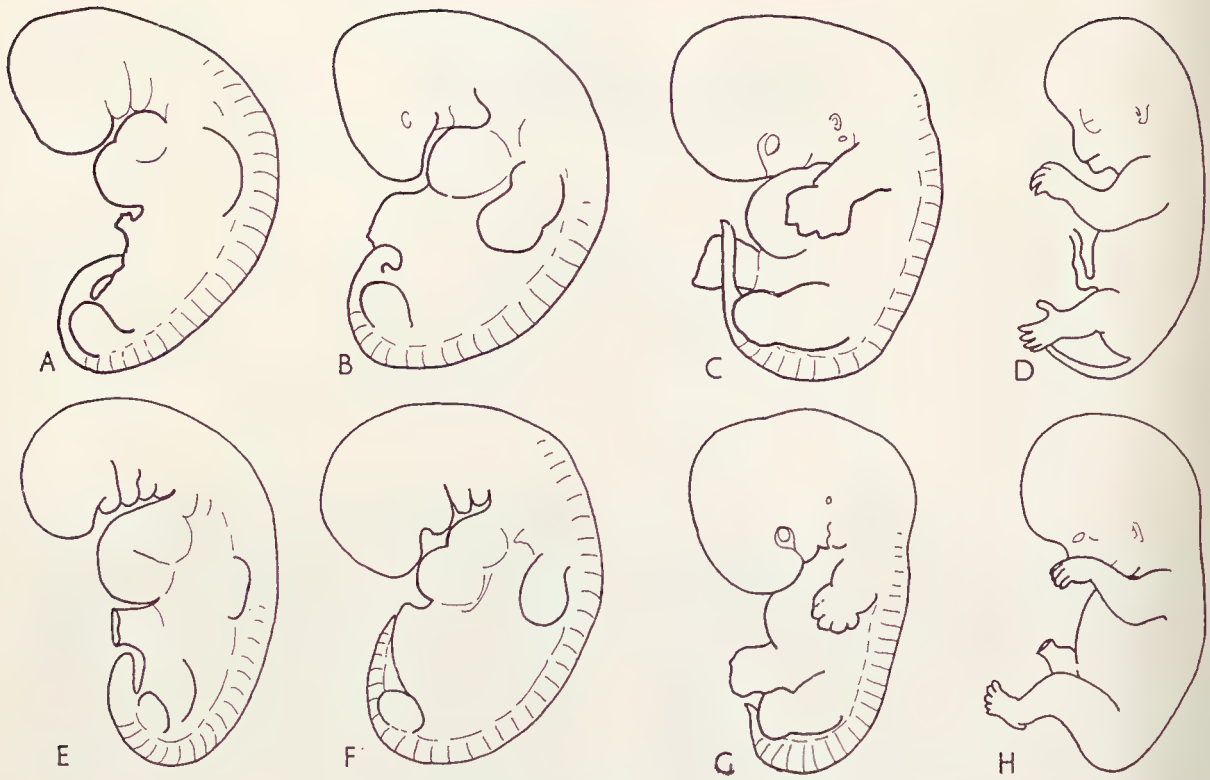

FIG. 1.—Comparative embryonic stages: A-D, macque; E-H, human (from Abbie, 1958a).

One such factor is the element of time. This has been largely neglected in most discussions on human evolution. Tonight I hope to show that timing in onset, speed, duration and cessation of development of many features has largely determined the physical bias that distinguishes man from what seem to be his nearest relations, and further, distinguishes some ethnic groups of men from others.

Before I start I should explain two terms I propose to use: one is "paedomorphism" (more or less synonymous are "foetalization" and "neoteny") which implies a tendency to retain embryonic, foetal or infantile standards of physical development; the other is "gerontomorphism" which implies a rushing on to physical maturity. In paedomorphism development and differentiation are retarded, in gerontomorphism they are accelerated (see Bolk, 1926; de Beer, 1940; Abbie, 1952a, 1958a; Hardy, 1954; and others).

TIMING

The Body as a Whole

In common with other animals (see Child, 1915) man shows a cephalo-caudal gradient of differentiation. Early evidence of this is the large head, tapering trunk and initial absence of limbs in the embryo (Fig. 1). Then the trunk differentiates and in succession the upper and lower limbs appear, enlarge and gradually assume their proper proportions. Thus as each region approaches developmental satisfaction the peak of the gradient gradually shifts distally in both trunk and the limbs. To describe this distal shift I have borrowed the botanical term "acropetalism" (Abbie, 1958a).

At the time of birth the human head occupies about one quarter of the total body length, the trunk about half and the inferior extremities approximately the remaining quarter (Fig. 2A). By the sixth year the head has dropped to only one-sixth of the stature and in the adult it is just over one-eighth. Growth in the trunk and superior extremities proceeds meanwhile at a moderate pace, but distal shift of the gradient peak causes the inferior extremities to extend with accelerating vigour so that they occupy more and more of the total stature and push the trunk progressively further from the ground (Fig. 2). In adult European males, in the outcome, the inferior extremities occupy nearly half the total stature, having doubled their relative proportions in some 20 years of differentiation.

These proportions may be affected in various ways. Whatever precipitates early maturation or retards growth—malnutrition, hypergonadism, hypothyroidism, achondroplasia, &c.—hampers extension of the lower limbs which end up shorter

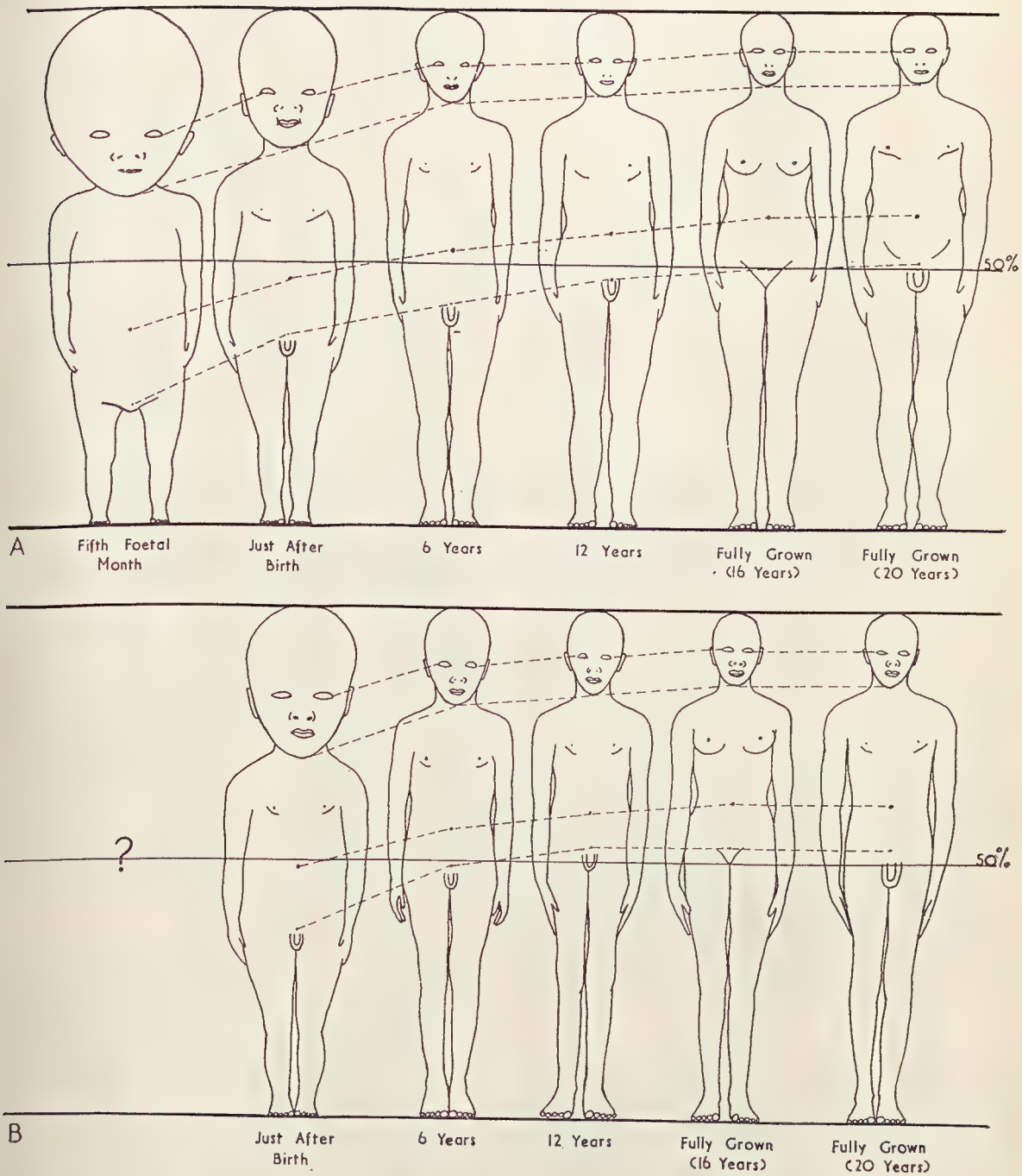

FIG. 2.—Progressive growth pattern in A. Europeans; B. Australian aborigines (from Abbie, 1958a).

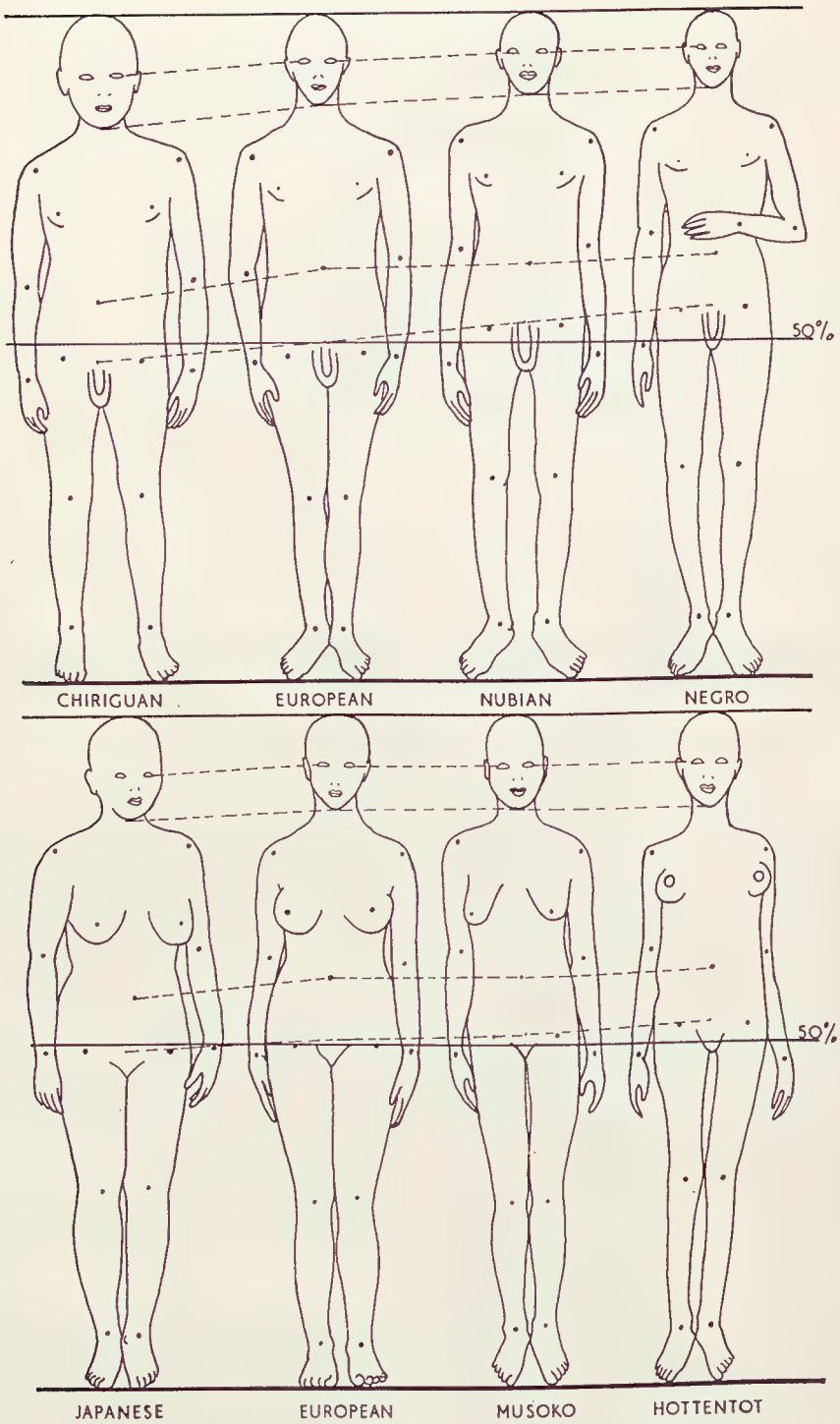

FIG. 3.—Comparison of proportions of various ethnic types drawn from photographs in Martin (1928).

than the norm, as in various kinds of dwarfs. And shorter legs are normal in adult females who stop growing some years earlier than males. It is also normal in some ethnic groups, e.g., mongoloids in China, Japan and the Americas, whose growing period does not seem to be curtailed, yet they retain such paedomorphism that their heads are relatively larger and their inferior extremities relatively shorter than in Europeans (Fig. 3). On the other hand, whatever delays maturation or accelerates growth—hypogonadism (eunuchoidism), hyperpituitarism—favours extension of the inferior extremities which appear disproportionately long. This is found normally in some ethnic groups, notably in Africa (Fig. 3). Keith (1919) has attributed these ethnic differences in proportion to a sort of ethnic hormonal distinction but his views have not received any real support.

One of the longer-legged peoples is the Australian Aborigine (Fig. 4). Up to about the fifth year his physical proportions differ little from those of Europeans then, quite suddenly, the inferior extremities make a spurt that gives the Aboriginal child of six the proportions of a European child of twelve (Abbie, 1957, 1958a). Thereafter the Aborigine stays that much ahead of the European until growth ceases (Fig. 2B). The reason for this sudden spurt is unknown but there is no doubt that the timing of its onset six years earlier than in Europeans is largely responsible for the final difference in proportions that distinguish the Aborigine from the European.

Intra-human ethnic differences in physical proportions can, therefore, fairly be attributed to differences in the timing accorded to the development of various parts of the body. This is more decidedly the case with intra-primate physical differences (Fig. 5). In the great apes differentiation of the body as a whole is considerably more advanced than in humans. Within the Pongid pattern the trunk and superior extremities show a marked relative acceleration in development, i.e., gerontomorphism; the inferior extremities, on the other hand, are relatively retarded, they are paedomorphic in comparison. It is as though the growth gradient is not given enough time to complete its job on the inferior extremities. And in this connexion it is of interest that maturation in the apes occupies only a little more than half the time required in man.

The Head

Comparison of the skulls of the major primates at the time of birth discloses that they are all closely similar (Fig. 6). In each case the calvaria is little more than a simple osteo-fibrous membrane for the brain (Abbie, 1947), and a rudimentary facial skeleton is suspended below. Subsequent differentiation proceeds at different rates in different animals. In most non-human primates the jaws enlarge rapidly forwards to occupy a predominant proportion of the total skull. The calvaria does not expand to the same extent so it develops various bony excrescences in the way of brow ridges, and sagittal and nuchal crests which provide additional muscle attachments although they are not necessarily associated with jaw size (Abbie, 1952a). In the human the jaws retain smaller proportions in comparison and the calvaria, being relatively large, has no need for the extra bony muscle attachments seen in the ape and remains pretty smooth. Of them all, the human skull has departed least from the foetal proportions it started out with—it is essentially undifferentiated, or paedomorphic. In most apes, on the other hand, differentiation of the skull as a whole has proceeded much further in half the time.

Apart from such obvious features human paedomorphism is shown in more subtle ways as in the thinner cranial bones, delayed closure of joints, tendency to retain a metopic suture, more forward siting of the foramen magnum, more open speno-maxillary fissure (Hone, 1952), increasing failure of the third molar teeth to erupt and so on. These features are accentuated where growth is arrested, as in dwarfs and in normal adult females.

However, while paedomophism predominates in the human skull it is not the only factor involved. Some features, such as the highly arched nose and prominent chin, must be considered more differentiated than in the apes and, therefore, relatively gerontomorphic. A case in point is the mastoid process—this is much better developed in man than in apes for, as Schultz (1957) points out, the human mastoid appears soon after birth and is practically maximal by adulthood while the gorilla mastoid does not begin to develop until after dental maturity and not till old age is it as large as in a young man. Timing has an important part in the development of all these features and, in some cases at least, it could be argued that the difference in timing towards gerontomorphism is adaptive (Abbie, 1958a).

Human cranial capacity and, therefore, brain size far exceeds that of any other primate. The gorilla, though it have three times the bulk of a big man, has a brain only half as large. The human brain is distinguished by both its great absolute size and its great relative weight in comparison with body weight (Abbie, 1958a). Again, timing helps to determine this human distinction. Schultz (1957) has shown that the cranial capacity of the human newborn is about 14 per cent of the body weight and this is much the same in the other major primates. In adult humans after twenty years the brain still accounts for 2.0 per cent of the body weight whereas in adult apes after only eleven years it has fallen to just 0.25 per cent—relatively, a bare tenth. This is another example of paedomorphism since, clearly, the human brain has departed less from the foetal proportion than has the ape: to one-seventh as against nearly one-seventieth.

Other Physical Characters

Table I shows a number of other features in which human distinctions depend upon retardation of development as compared with other primates. The period of gestation, the total growing period and expectation of life, onset and completion of ossification and dentition, development of pigment and hair are all progressively slowed down as we go from monkeys through apes to man. Indeed, a number of developmental features—pigmentation, hair growth, dentition—despite the more pro-

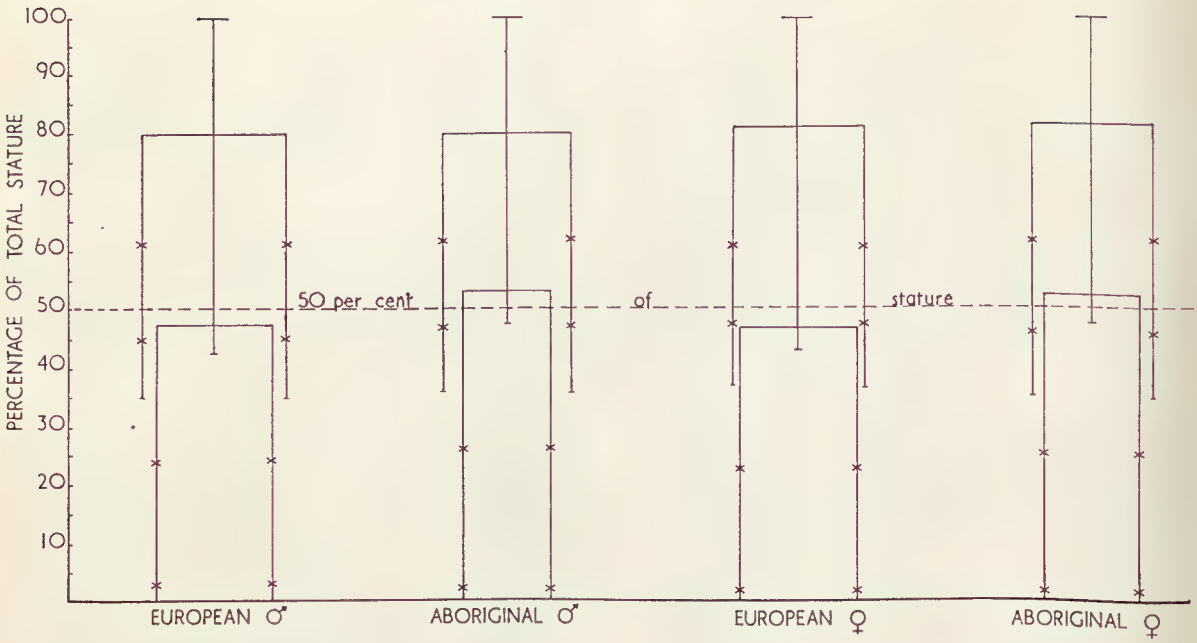

FIG. 4.—Comparison of proportions of adult male and female Europeans and Australian aborigines (redrawn from Abbie, 1957).

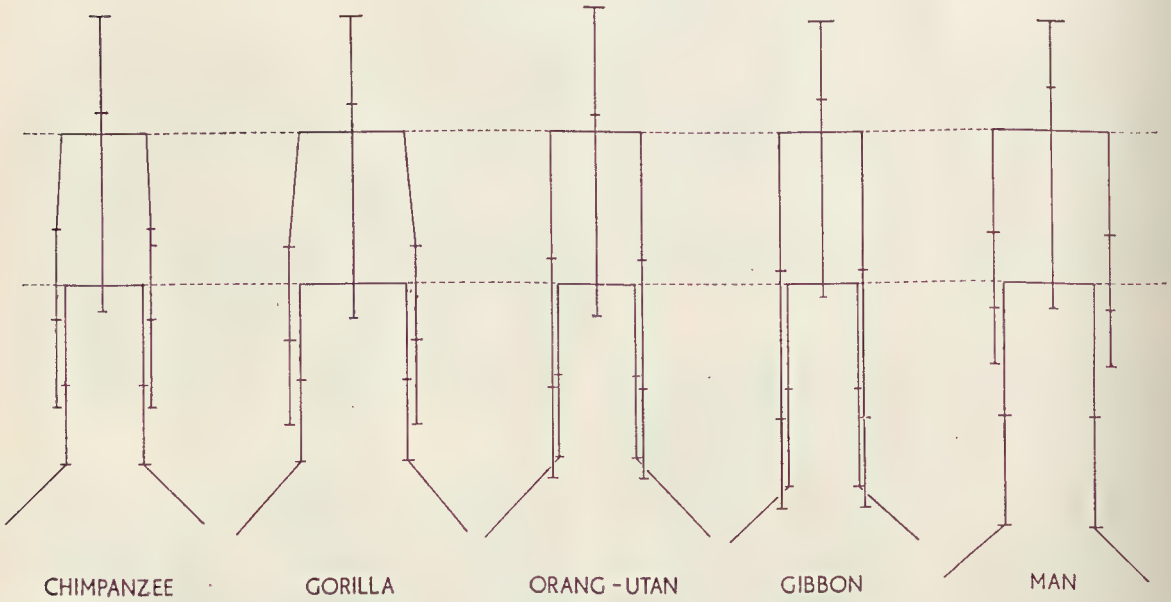

FIG. 5.—Comparison of proportions of man and other primates, taking trunk length as a common basis (redrawn and modified from Martin, 1928).

tracted growing period, may never reach completion at all in man. I must add that while pigmentation does become complete in some human groups this should (provisionally) be attributed to natural selection, not to alleged sub-human affinities—in many Aborigines completion of pigmentation is delayed until adolescence or later (Abbie and Adey, 1963.

CONCLUSION

Acceleration of development may lead to high differentiation, i.e., gerontomorphism; prolonged growth at a lesser speed could finally produce the same result: but prolonged growth is simply retention of the foetal tendency to grow, i.e.,paedomorphism. Since two such diverse processes may have a similar outcome it is essential to try to avoid confusion over which is involved. This may be done by considering how much is achieved in a given time. The gorilla, for example, attains far more total differentiation than does the human in twice the time; that is overall gerontomorphism. The ape's inferior extremities are paedomorphic in comparison with the human but it must be conceded that apes have only half the time in which to extend their inferior extremities. Were it not for the total gerontomorphic trend in apes we might be in doubt over how to class the development of their lower limbs. On the other hand, ethnic groups which end up with shorter inferior extremities than Europeans *in the same time* are relatively paedomorphic, those with longer inferior extremities are gerontomorphic.

TABLE 1

Primate	Gestation (Weeks)	Pigmentation	Hair Covering	Carpal Ossification Centres at Birth	First Dentition (Months)	Second Dentition (Years)	Growing Period (Years)	Life Span (Years)
Macaque	24	Completed early in gestation	Completed during gestation	All centres	0.6-5.9	1.6-6.8	7	25
Gibbon	30	Onset during gestation, completed after birth	Onset during gestation, completed after birth	2-3	1.2-?	?-8.5	9	33
Orangutan	39			2-3	4.0-13.0	3.5-9.8	11	30
Chimpanzee	34			2	2.7-12.3	2.0-10.2	11	35
Gorilla	37			?	3.0-13.0	3.0-10.5	11	35
Man	40	*Coloured,* Onset mainly after birth. *White,* Never	Never completed	0	6.0-24.0	6.0-20.0	20	70+

Data from Bolk, de Beer and Schultz (slightly modified).

The tail, so well developed in monkeys, is suppressed almost to extinction in man and the apes. This suppression is manifest in early foetal life (Fig. 1) and must be attributed to paedomorphism.

The longer inferior extremities in man are gerontomorphic as a whole but the feet show exceptions. In all non-human primates the great toe is widely separated from the others, like the thumb in the hand, and this is evident early in pre-natal life (Fig. 1). In man the great toe is not only closely apposed, its metatarsal is firmly attached to the other metatarsals by the deep transverse ligament of the sole (Wood Jones, 1944)—an attachment found in no other primate. Separation of the toes is determined by a series of radial splits around the periphery of the footplate (Fig. 1G). In non-human primates the split for the big toe extends deeply, producing a highly mobile organ. In man the splitting is partly suppressed, a further example of paedomorphism. Suppression of development is also apparent in the other human toes which do not grow so long relatively as in the apes (Schultz, 1957). However, not all foot developments in man are paedomorphic: the strong specialization in the talus and calcaneum (astragalus and os calcis) to form the human heel is markedly gerontomorphic. This gerontomorphism in the heel is adaptive and permits man to walk upright; the apes are essentially quadrupedal.

I have no space here to consider other human adaptions to the upright posture but there are many (see Schultz, 1957).

A factor to be taken into account also is the environment. This is loosely recognised in the term "adaptation" but, while most animals are very well adapted to their environment, we must note that man is changing his and this is reflected in his physique. Not only has improved environment, in the way of improved nutrition for example, affected such characters as stature, body weight, &c., it is actually producing more profound changes, e.g., in head form (Boas, 1940; Abbie, 1947; Kaplan, 1954). When we have some idea of how the perfect genetic make-up can respond to the ideal environment (if either exists) we shall have some way of measuring more precisely the true effects of timing in differentiating man from other primates.

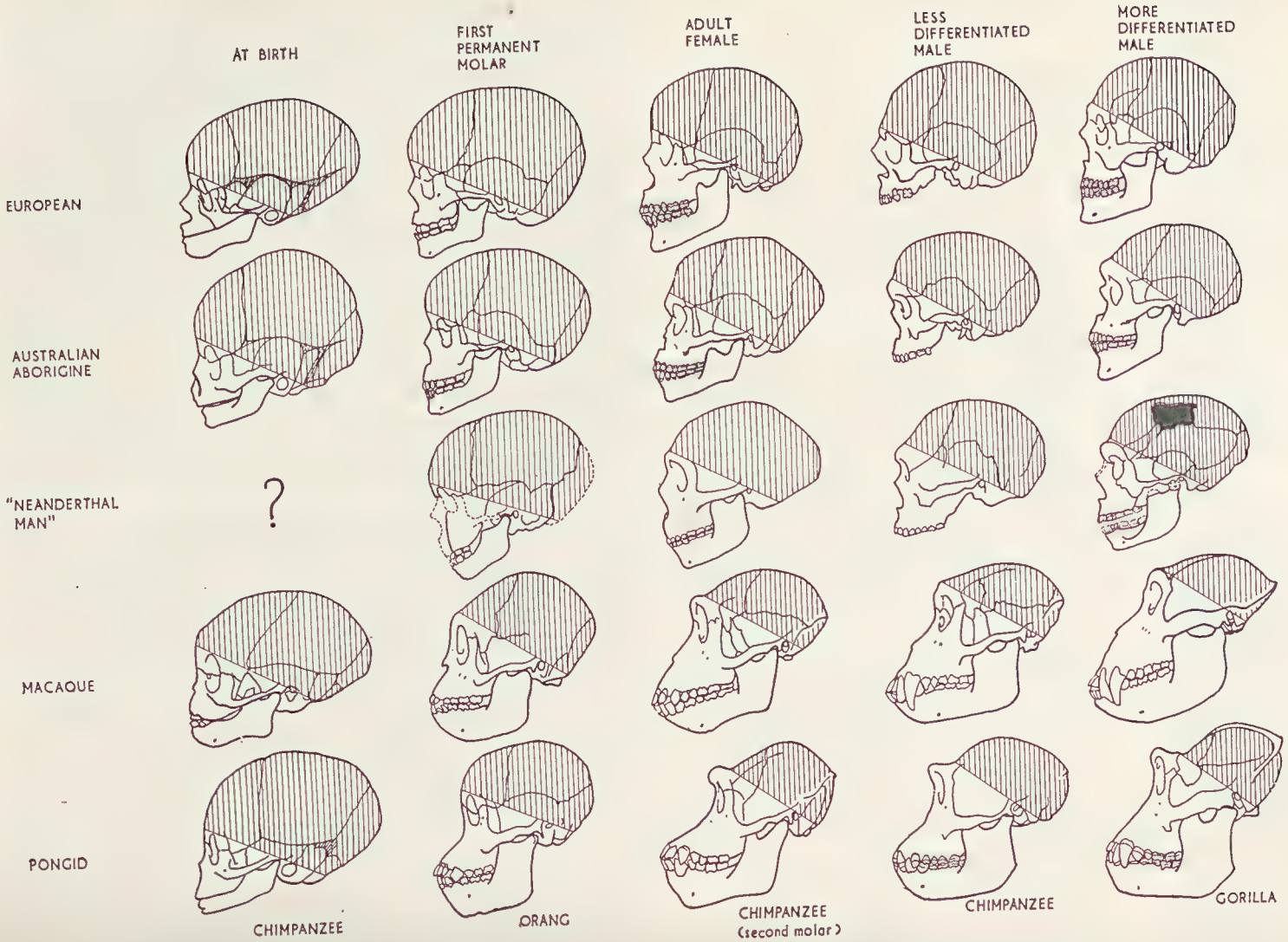

FIG. 6.—Comparison of the growth pattern of skulls of some humans and other primates (redrawn and modified from Abbie, 1952a). Hatching indicates approximate proportion given to the brain.

In tracing the development of different primates we are, really, watching different expressions of what is essentially the same process—variations on a common theme. All start off at about the same point and their differences appear only when differences in the timing of secondary developments become apparent.

Development is like a cinematographic film that comprises the whole of differentiation and can be run slow or fast as desired, or at different speeds at different times. In gerontomorphism the film—wholly or in part—is run through fast: development is accelerated, parts rush to completion, details may become exaggerated, blurred over or completely lost. But more film can be run through in the time available, and much more can be achieved in differentiation. In paedomorphism the film is run through slowly, the whole process is drawn out, features are unfolded in greater detail and hitherto unsuspected aspects show up. However, much less film can be run through in the time available: even when the time is doubled, as it is in man, the final achievement in differentiation may still fall short of extremes if the running rate is very slow. At present we have no idea of the proper speed of the film or even its length, although reference to primate morphology and human developmental variations is beginning to give us some idea of how the picture can be changed under different conditions.

To revert to our original theme: we may conclude that in the development of all primates there is a mixture of paedomorphism and gerontomorphism and that the features that distinguish man peculiarly from the others are, on balance overwhelmingly the outcome of paedomorphism—of delayed timing that imposes a distinctive human bias upon an assemblage of characters that are basically alike for all primates. The factor of timing is, itself, part of the specific heritage of every primate and it determines in what order, at what rate and to what extent any character shall unfold. To put it differently, the germ-plasm of each primate is—as electronic engineers would say—"programmed" from the outset to determine the onset, sequence and the rate of unfolding.

Clearly, then, when we are seeking for man's relations and his line of evolution we shall profit little from studying the end products—the adults—too closely. We must seek for relationships in embryos, and the earlier we look the closer the relationship will be. More specifically, we must look for the germinal timing mechanism that regulates the progress of any primate along its predetermined course of development. It is quite conceivable that a minor genetical twist in the timing mechanism of any primate could have determined the course of development that led to man. That could have happened quite suddenly and at any time—even very recently. Moreover, as Hardy (1954) has pointed out, neotenous changes afford an avenue of escape from ancestral specializations that would otherwise preclude any progress along more generalized lines—this applies especially to man (Abbie, 1952b).

To sum up, the view put forward here as a working hypothesis has several advantages:—

(a) it involves nothing unknown in biological mechanisms;
(b) it shows how man could have emerged quite suddenly and within relatively recent times;
(c) it disposes of the problem created by the absence of satisfactory "missing links"—they are not required.

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THE BIOLOGY OF HYMENOLEPIS MICROSTOMA (DUJARDIN)

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(With 7 figures in the Text)

ABSTRACT

The occurrence of cysticercoids of *Hymenolepis microstoma* (Dujardin) in *Cestrinus punctatissimus* Pascoe (Tenebrionidae) and the adult cestode in *Mus musculus* L. respectively, from the Domain, Hobart, Tasmania, is recorded. Five of the 14 mice and 36 of the 1,356 *C. punctatissimus* examined were found infected.

Both the adult and the larval stages of the cestode are described.

Experimentally infected white mice voided gravid proglottides 17 days after ingestion of the cysticercoids. The cestode grew 100 mm. in length in the first 16 days.

The oncosphere has a U-shaped penetration gland and is surrounded by four membranes.

INTRODUCTION

Whilst examining insects for cysticercoids of *Oochoristica vacuolata* Hickman, the larval stage of another cestode was found. This subsequently proved to be the cysticercoid of *Hymenolepis microstoma* (Dujardin 1845) hitherto unknown to occur in Tasmania or elsewhere in Australia.

The biology and distribution of *H. microstoma* has been described by Joyeux and Kobozieff (1927, 1928) and Dvorak *et al.* (1961). However, in their summary of the distribution of the parasite, the latter authors omitted to mention the occurrence of the adult cestode in the Belgian Congo (Mahon 1954).

In view of the account of Joyeux and Kobozieff, no attempt has been made in the present investigation to study the development of the cysticercoid.

MATERIALS AND METHODS

Cysticercoids identified as those of *Hymenolepis microstoma* were obtained from naturally infected specimens of the tenebrionid *Cestrinus punctatissimus* Pascoe collected from the Domain, Hobart.

Four white mice were raised under controlled conditions in the laboratory and used for experimental infection. Three of them were each fed with an infected specimen of the tenebrionid. The fourth mouse was made to swallow three cysticercoids from the haemocoel of an infected beetle by pipetting them down its throat. The faeces of the mice were then examined regularly for eggs of the cestode. Of the three mice which were fed with infected beetles, one was dissected and examined at the end of 16 days, the other two at the end of 22 days. The fourth mouse, which was fed with three cysticercoids, died at the end of 175 days and was then dissected and examined. A record was made of the location, number, maturity and size of the cestodes present.

During the years 1956 to 1959 a total of 1,356 *C. punctatissimus* were collected from the field and examined. The infection with cysticercoids of *H. microstoma* was recorded and the centres of high infection noted. Snap-traps were then set in these localities and 14 specimens of *Mus musculus* L. were caught. On dissection five were found infected with *H. microstoma*. The stomach content of the mice and the position, number, size and maturity of the cestodes present recorded.

On removal from the host the tapeworms were placed in water and allowed to relax. They were then fixed in Bouin's fluid. Three of the gravid worms from the experimentally infected mice and three from those naturally infected were stained in Ehrlich's haematoxylin and mounted. The scolices of two worms from the experimentally and two from the naturally infected mice were compressed and mounted without staining. The eggs from gravid segments were stained in an aqueous solution (1 : 10,000) of neutral red. Observations were made on both living and preserved cysticercoids. The latter were fixed in Bouin's fluid and mounted either unstained or after staining in alum carmine.

INFECTION OF THE PRIMARY HOSTS

On dissection the four white mice were all found infected. The degrees of infection were 2, 7, 8, 15. The mouse containing two worms had been fed with only three cysticercoids. The number of cysticercoids in the beetles fed to the other mice was not determined.

The 14 mice collected in the field were caught during the period 27/5/'59 to 5/6/'59. Five were found to be infected and these contained 1, 2, 5, 8 and 14 worms respectively. All the worms were gravid.

In both experimentally and naturally infected mice the majority of the cestodes had their scolex attached in the bile duct. The strobila of the longer specimens extended into the duodenum. However, in one instance the posterior part of one worm was observed coiled up in the gall bladder. On another occasion, in a mouse infected with 14 tapeworms, an entire worm was found in the gall bladder. The worm, however, was dead and partly decomposed. Only once was a tapeworm found attached to the duodenum. As this tapeworm was immature and found in the experimentally infected mouse which was dissected only sixteen days after infection, it is probable that it may have failed to establish itself in the bile duct and would have eventually been voided.

The stomachs of the 14 mice collected in the field contained seeds (6), Araneae (6), Lepidoptera larvae (4), Hemiptera (1) and Formicidae (1) (frequency indicated in parentheses). None of the mice contained *C. punctatissimus.*

DESCRIPTION OF THE ADULT CESTODE

The specimens from the naturally infected *Mus musculus* were identical with those from experimentally infected mice. The following is an abridged description of the mature specimens.

Length of cestode, 94-190 mm. Width of strobila, 1.25-2.0 mm. *Scolex* (excluding rostellum)—length, 138-195 micra; width, 230-270 micra. *Suckers*—length, 64.4-90.0 micra; width, 55.2-87.0 micra. *Rostellum*—length, 46-67 micra; width, 46-49 micra. *Rostellum sac*—length, 103.5-161.0 micra; width, 103.5-138.0 micra. *Hooks*—24-26 arranged in a single crown. *Length of hooks*—from end of handle to point of blade 13.8-15.0 micra; from end of guard to point of blade 5.8-9.2 micra; from end of guard to end of handle 12.7-15.0 micra. *Segments*—600-900; broader than long (mature 0.9 x 0.14 mm., gravid 1.53 x 0.24 (mm.). *Genital pores*—unilateral and on the right, $\frac{1}{3}$ of the length of the segment from the anterior margin. *Excretory vessels*—diameter of dorsal vessel, 5.8 micra; diameter of ventral vessel, 9.2 micra. *Genital ducts*—pass dorsal to the lateral nerve and both excretory vessels. *Testes*—number, 3, very rarely 5 or 6; position variable (see later); transversely oval, 115 x 103-127 x 115 micra (in mature segments). *Cirrus*—short, 46 micra long, surrounded at its base by gland cells. *Cirrus pouch*—elongated and reaching the lateral nerve and excretory vessels; 138 x 53-161 x 64 micra. *Internal seminal vesicle*—fills greater part of pouch; length, 115-138 micra. *External seminal vesicle*—elongated, expanded distally; length (approx.), 173 micra; maximum diameter, 69 micra. *Ovary*—situated slightly to the poral side of the middle of the segment; transversely elongated and with 2 to 3 lobes; length 69-80 micra; width, 230-299 micra. *Vitelline gland*—posterior to the middle of ovary, compact and transversely oval; length, 46-58 micra; width, 69-92 micra. A *Vaginal sphincter* is present at poral end of vagina. *Seminal receptacle*—elongated, expanded distally; length (approx.), 138 micra; maximum diameter, 83 micra. *Uterus*—dorsal, sac-like. *Eggs*—oval, 64.4 x 60.0-90.0 x 60.0 micra; with 4 membranes (see later) enclosing the oncosphere; 2-3 polar filaments. *Oncosphere*—25.3 x 24.2-27.6 x 25.3 micra; provided with penetration glands. *Oncospheric hooks*—ventro-lateral hooks, stout, length 18.4 micra; dorso-lateral hooks narrow, length, 17.3 micra; median hooks narrow, length , 20.7 micra (Figs. 1, 2, 3, 4 and 5).

Fig. 1.—Rostellar hooks.

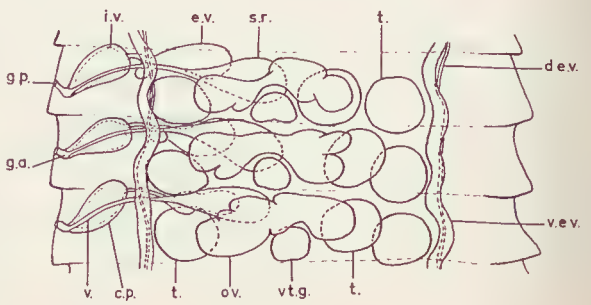

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Fig. 2.—Ventral view of mature proglottides (uterus not shown). c.p., cirrus pouch; d.e.v., dorsal excretory vessel; e.v., external seminal vesicle; g.a., common genital atrium. g.p., common genital pore; i.v., internal seminal vesicle; ov., ovary; s.r., seminal receptacle; t., testis; v., vagina; v.e.v., ventral excretory vessel; vt.g., vitelline gland.

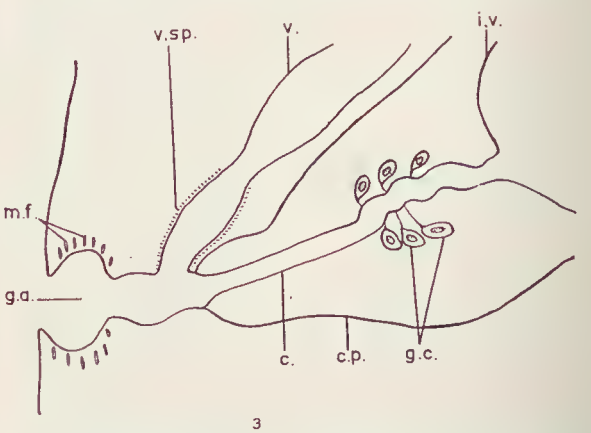

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Fig. 3.—Ventral view of the reproductive ducts in the region of the genital atrium in a compressed semi-gravid proglottis. Vagina displaced from its position ventral to the cirrus pouch. c., cirrus; c.p., cirrus pouch; g.a., common genital atrium; g.c., gland cells. i.v., internal seminal vesicle; m.f., muscle fibres around atrium; v., vagina; v.sp., vaginal sphincter.

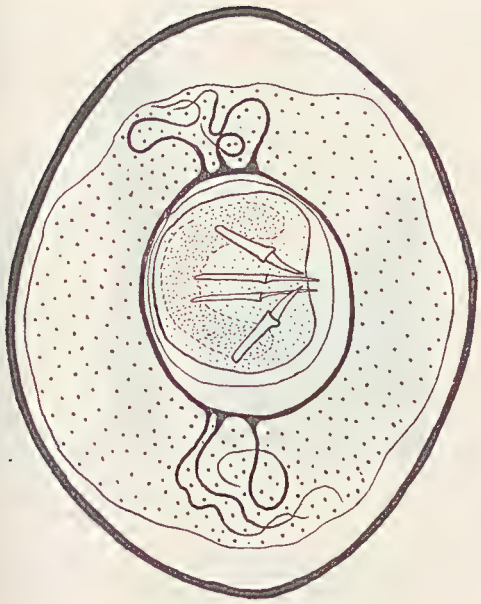

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FIG. 4.—Egg from a gravid proglottis.

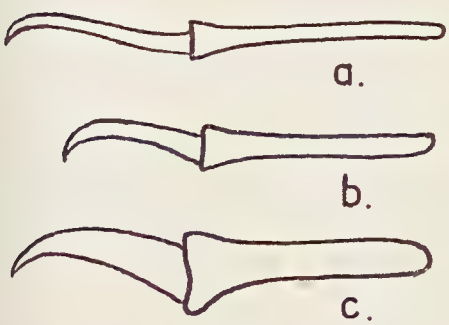

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FIG. 5.—Hooks of the oncosphere. *a.* median hook, *b.* dorso-lateral hook, *c.* ventro-lateral hook.

As indicated above some variations in the number and arrangement of the testes were observed. Thus in a strobila in which the testes were evident in 377 of the proglottides, there were three testes in each 374 segments, five in each of two and six in one. In 318 of the segments containing three testes, two testes were situated to the left of the vitelling gland (i.e., aporal) and one on the right (poral); in 53 segments the three testes were aporal; in the remaining 3 segments one testis was aporal and two poral. One of the 2 segments containing five testes had three on the left and two on the right, the other had two on the left and three on the right. In the segment containing six testes, three were on the right and three on the left.

From the outside inwards, the investments of the oncosphere are as follows:—(1) an outer rather rigid oval shaped membrane; (2) a thin flexible membrane closely applied to the inner side of the first investment; (3) a granular fluid; (4) a thick rigid oval shaped membrane, the embryphore, 34.5 x 30.0-37 x 30 micra, from the poles of which arise 2 to 3 filaments that project into the fluid filled space; (5) a thin membrane closely surrounding the oncosphere (Fig. 4).

GROWTH IN THE LENGTH OF THE ADULT CESTODE

Eggs and partly disintegrated proglottides were found in the faeces of experimentally infected mice after the sixteenth day following infection. The seven cestodes from the mouse dissected and examined on the sixteenth day measured 17, 33, 40, 85, 87, 92 and 112 mm. long respectively. Three chains of segments were also found in the duodenum indicating that shedding had commenced. Eight cestodes from one mouse and 15 from another examined on the twenty-second day varied in length from 50 to 127 mm. The two cestodes from the mouse fed with 3 cysticercoids and examined 175 days afterwards measured 160 mm. in length. It appears that the cestode commences to shed proglottides when it is about 100 mm. long.

INFECTION OF THE INTERMEDIATE HOST

The gravid proglottides of *H. microstoma* are shed from the strobila as chains of segments. These partly disintegrate as they pass through the intestines and are no longer active when voided with the faeces of the host. As a result of the breaking up of the proglottides the eggs become dispersed through faecal material. To become infected, the tenebrionid must feed either on the faeces containing the eggs of the cestode or on some vegetation contaminated with the eggs after disintegration of the faecal pellets.

TABLE 1

Degree of infection of *Cestrinus punctatissimus* with cysticercoids of *Hymenolepis microstoma*.

Number of cysticercoids per specimen of *C. punctatissimus*	Number of specimens of *C. punctatissimus* infected
1	4
2	3
3	2
4	2
5	1
6	1
7	1
8	1
9	2
11	1
13	1
17	1
24	2
38	1
42	1
50	1
86	1
93	1
98	1

Thirty-six (2.65%) of the 1,356 *Cestrinus punctatissimus* dissected and examined were found infected with cysticercoids of *H. microstoma*. The monthly percentage infection is shown in figure 7. Nearly 39% of the infected specimens were collected during August. The degree of infection ranged from 1 to 98 (see Table 1).

The cysticercoids were free in the haemocoel of the insect and generally among the muscles in the metathorax and the organs in the abdomen. However, on one occasion they were also found among the muscles in the head.

DESCRIPTION OF THE CYSTICERCOID

The body of the fully developed cysticercoid is divisible into an anterior almost spherical cyst enclosing the scolex and a posterior spherical or elongated solid cercomere (Fig. 6).

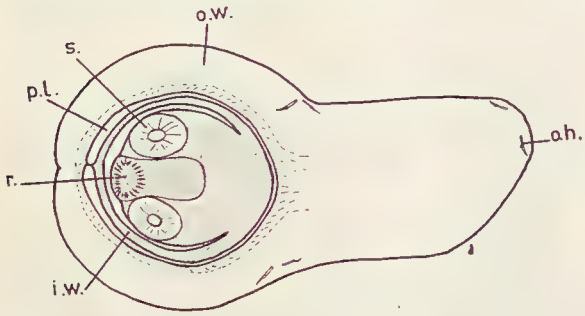

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FIG. 6.—Cysticercoid. i.w., inner wall; o.h., oncosphere hook; o.w., outer wall; p.l., primative lacuna; r., rostellum. s., sucker.

The overall length of the cysticercoid varies from 0.3 to 7.7 mm.; the diameter of the cyst from 150 to 225 micra and the size of the cercomere from 0.15-7.4 mm. long and 0.15-0.49 mm. wide.

With few exceptions, cysticercoids with long "tails" were found only in beetles infected with few (9 or less) larvae. Those from heavily infected beetles almost invariably had a short cercomere (i.e., less than 0.5 mm.).

The cyst has an outer and inner wall separated by the nearly obliterated primitive lacuna. The outer wall consists of (1) a cuticle continuous with that covering the cercomere, (2) a cellular layer generally about 11.5 micra thick and continuous with the subcuticular layer of the cercomere, and (3) a layer (approximately 9 micra thick) of muscle fibres which are continuous with the circular and longitudinal fibres in the cercome. The inner wall is thin and encloses the scolex. It is cellular and contains numerous large granules. Posteriorly the wall merges with the base of the scolex.

The external opening of the canal formed when the scolex was withdrawn into the cyst is closed. It is indicated externally only by a slight depression in the outer and inner walls. The inner part of the canal is retained as the cavity in front of the scolex enclosed by the inner wall.

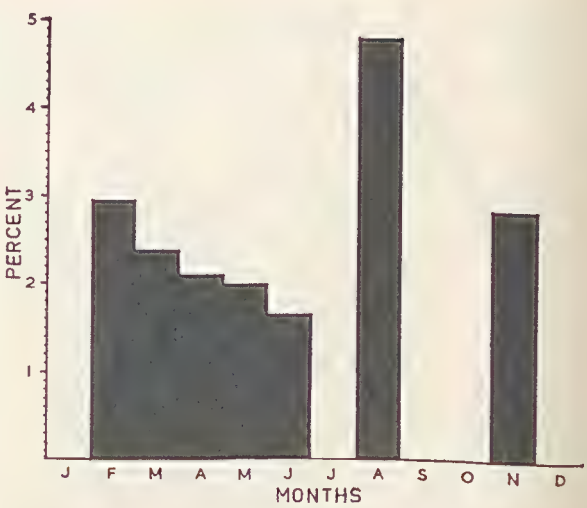

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FIG. 7.—The monthly percentages of the total number of *Cestrinus punctatissimus* collected from 1956 to 1959 and infected with *Hymenolepis microstoma*.

DISCUSSION

Only six species of cestodes, which in their adult stage normally inhabit the bile duct of their host, have so far been recorded, namely, *Hymenolepis microstoma*, *Progamotaenia festiva* (Rud.), *Thysanosoma actiniodes* Dies., *Stilesia hepatica* Wolff., *Crossotaenia baeri* Mahon and *Wyominia tetoni* Scott. Joyeux and Kobozieff (1928) in their description of *H. microstoma* state that the scolices may be attached in the duodenum or bile duct. However, Dvorak *et. al.* (1961) found this cestode attached in the duodenum only twice in the hundreds of infected mice which they examined. Likewise I found attached outside the bile duct only one of the 62 tapeworms from 9 mice found to be infected.

Adults of *H. microstoma* have been recorded from the following mammals:— *Mus musculus* L., *Rattus norvegicus* Erxl., *R. rattus* L. *Mastomys coucha* Smith, *M. coucha ugandae* Wint., *Arvicanthis abyssinicus* Rüpp, *Meriones shawi* Rozet, *Microtus agrestis* L., *Sigmodon hispidus* Say and Ord, *Apodemus* sp., *Promomys* sp., *Dendromus* sp. and *Leggada* sp. see Joyeux and Baer 1936, Mahon 1954, Yamaguti 1959. In addition, Dvorak *et al.* (1961) succeeded in infecting *Mesocricetus auratus* Waterhouse, but found that the cestode had an adverse physiological effect upon this host. The same authors were unable to infect rats with *H. microstoma*.

In Table 2 data on the characteristic features of *H. microstoma* as given by several authors are listed along with data for the specimens from Tasmania. The characteristics of the Tasmanian material are seen to agree essentially with those given by other workers on *Hymenolepis microstoma*. Previous descriptions, however, make no mention of the presence of a penetration gland

in the oncosphere, gland cells at the base of the cirrus and a vaginal sphincter. Moreover, other authors have recognised only two or three membranes around the oncosphere, whereas I observed four. Recently Voge and Berntzen (1961) found that the oncosphere of the related species, *H. diminuta*, is surrounded by five membranes. It therefore seems likely that a further membrane may yet be found surrounding the oncosphere of *H. microstoma*.

microstoma they were using. However, they succeeded in infecting *Tribolium confusum*, *T. casteneum* and *Oryzaephilus surinamensis*. As a result of the present investigation the tenebrionid *Cestrinus punctatissimus* may be added to the list of natural intermediate hosts of this tapeworm.

ACKNOWLEDGMENT

I wish to thank Dr. P. B. Carne of the C.S.I.R.O. for help in identifying the tenebrionid, *Cestrinus punctatissimus*.

TABLE 2.

Data on characteristic features of *H. microstoma*. Measurements except where indicated are in micra.

Feature	Luhe 1910	Joyeux and Kobozieff 1928	Mahon 1954 (*a*)	Mahon 1954 (*b*)	Dvorak *et. al.* 1961	Present work
Total length (mm.)	160	80-350	90	—	100-280	94-190
Maximum width (mm.)	2.1	2	2	—	—	1.25-2.0
Scolex: width	450	200	274-328	187-288	—	230-270
Rostellum: diameter	—	100	—	58-79	—	46-69
Suckers: diameter	100	60	59-68	86-108	—	55-90
Hooks:						
number	30	27	18-25	19-24	23-28	24-26
length	11	15	11-15	10-14	15	13.8-15.0
Dorsal exc. ves: diameter	—	5	—	—	—	5.8
Ventral exc. ves.: diameter	—	27 x 10	—	—	—	9.2
Cirrus pouch:						
length	—	135	144-180	100-198	—	138-161
width	—	50	54-58	40-65	—	53-64
Testes	—	170 x 120	—	—	70-130	115-127
Ovary	—	—	—	—	300 x 55	230-299 x 69-80
Outer membrane of egg: diameter	90 x 82	90 x 80	61-72	—	75-90	64.4-90.0 x 60.0
Embryophore: diameter	41	40	—	—	—	34.5-37.0 x 30.0
Number of polar filaments	—	2	—	—	3-5	2-3
Oncosphere: diameter	32	30	36-40	31-43	—	25.3 x 24.2-27.6 x 25.3
Embryonic hooks: length	18	17-20	—	—	—	17.3-20.7
Cysticercoid (diameter of anterior cyst-like region)	—	170-200	—	—	—	150-225

(*a*) * from *Arvicanthis & Mastomys;* (*b*) * from *Mus & Meriones.*

In the present study, the rate at which the cestode was found to grow in its definitive host (100 mm. in 16 days) is comparable with that found by Joyeux and Kobozieff (1928) and Dvorak *et al.* (1961).

Cysticercoids of *H. microstoma* have been recorded (see Joyeux and Kobozieff (1928), Joyeux and Baer (1936) and Dollfus (1950) from the following insects—:

Coleoptera:
Tenebrionidae—*Tenebrio molitor, T. obscurus, Cerandia cornutus.*
Geotrupidae—*Geotrupes sylvaticus.*
Trogositidae—*Trogosita mauritanica.*
Orthoptera: *Dolichopoda linderi.*
Dermaptera: *Anisolabis annulipes.*
Aphaniptera: *Ceratophyllus fasciatus.*

Dvorak *et al.* (1961) found that *Tenebrio molitor* was refractory to infection with the strain of *H.*

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A NEW SPECIES OF TUCKERELLA (ACARINA, TETRANYCHOIDEA, TUCKERELLIDAE) FROM TASMANIA

by

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(With 11 text figures)

ABSTRACT

A new species of the genus *Tuckerella* Womersley 1940 is described from native plants in Tasmania. Descriptions of males and immature stages are included. The record of *T. pavoniformis* (Ewing) from Australia is questioned.

INTRODUCTION

The family Tuckerellidae was erected by Baker & Pritchard (1953) to include the single genus *Tuckerella* Womersley. At that time only two species *T. ornata* (Tucker) and *T. pavoniformis* (Ewing) were known. Subsequently Womersley (1957) described a further species *T. spechtae* from South Australia.

A fourth species has now been found in Tasmania breeding on native host plants. The collections included females, males, larvae and nymphs, whereas in the three previously described species only females had been recorded.

Womersley (1957) however, had described *T. spechtae* from a single specimen designated as a female. In his description he stated that it had a dorsal sensory rod on Tarsi III and IV similar to those on Tarsi I and II.

Examination of the males of the new species described herein revealed that the presence of a sensory rod on Tarsi III and IV was a male character only. A re-examination was therefore made of the holotype slide of *T. spechtae* Womersley. Although the specimen is in poor condition it is a male and not a female as designated.

A revised key suitable for adults of either sex and including the new species has therefore been prepared.

TUCKERELLA FLABELLIFERA sp.n.

Female Figs. 1, 2, 3.

Colour in life red with dorsal and caudal setae pale brown. Body elongate oval, dorsum reticulated, with suture lines between propodosoma and metapodosoma and between latter and opisthosoma. Eyes two on each side. Body with 4 pairs of palmate dorsals propodosomals and 18 pairs of similar dorsal hysterosomals. Last 4 palmate setae on dorsum with outer pair larger than inner pair and placed anterior to inner pair. Caudum with 5 pairs of ciliated flagellate setae each longer than the body. Two small foliaceous setae in a mediocaudal position between the long flagellate setae and a similar seta between the second and third and fourth and fifth flagellate setae on each side. All caudal setae arising from tubercles arranged in a straight line. Palpus five segmented, first segment short, fifth segment long and slender, bearing distally, a blunt sensory rod and two curved sensory setae. Three tactile setae along length of fifth segment. Fourth segment with a slender spur slightly shorter than fifth segment and bearing three tactile setae. Peritremes protruding as long narrow tubes laterally over. Legs I. Legs eight, short and stubby. Legs I-III with palmate dorsal setae on tibiae, femora and genua; Leg IV with slender dorsal setae. Tarsi with two stout claws and pulvillus; pectinate series of tenent hairs from bases of claws and on pulvillus. Tarsus I with two blunt sensory rods, the distal one being the longer (ratio, distal rod : proximal rod, 1 : 0.6) Tibia I and Tarsus II each with a single short sensory rod. Ventral setation of body as in Fig. 2. In genito-anal region there are nine pairs of setae arranged as follows:—3 pairs of primary genital setae along sides of vulva, 2 pairs of secondary

KEY TO ADULTS OF THE KNOWN SPECIES OF TUCKERELLA WOM.

1. Last four palmate setae on dorsum with outer pair smaller or subequal to inner pair 2
   Last four palmate setae on dorsum with outer pair larger than inner pair 3
2. Caudum with five pairs of long flagellate setae .... *ornata* (Tucker)
   Caudum with seven pairs of long flagellate setae .... *spechtae* Wom.
3. Caudum with five pairs of long flagellate setae .... *flabellifera* sp.n.
   Caudum with six pairs of long flagellate setae .... *pavoniformis* (Ewing)

FIG. 1.—*Tuckerella flabellifera*: dorsal aspect of female.

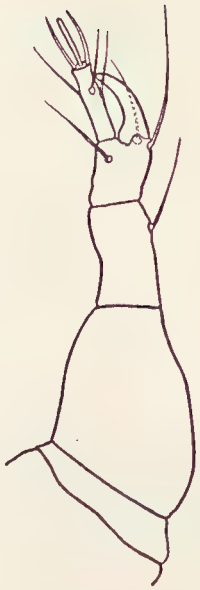

FIG. 3.—Female palp.

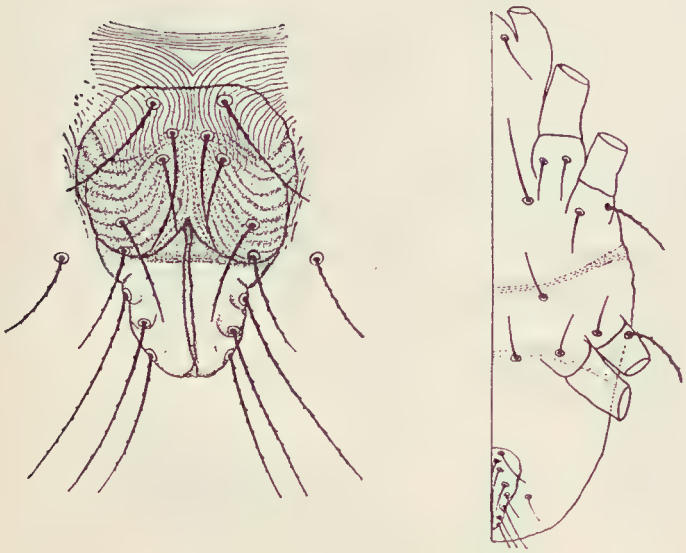

FIG. 2.—Ventral setation of female.

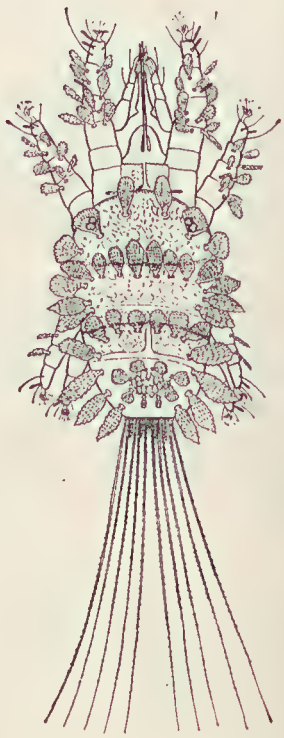

FIG. 4.—Dorsal aspect of male.

genital setae anterior to these on folds of oviduct; 2 pairs of ventral setae close to anterior margin of folds of oviduct. Anterior to these a single pair of medioventral setae and a single mediolateral seta on each side of the genital area. Dimensions of female idiosoma shown in Table 1.

Male Figs. 4, 5, 6, and 7.

Similar in general appearance to female. Dorsal reticulation on opisthosoma in a pattern with two clear transverse bands joined by a clear medial band. Dorsal and caudal setae similar to female in number, distribution and shape except that anterior pair of dorsal propodosomals are broad and truncate rather than pointed. Tarsus I with 2 sensory rods, the distal one being the longer. This distal rod is equal in length to that in female but the proximal one is longer than the equivalent rod in female. (Ratio, distal rod : proximal rod, 1 : 0.8) Tibia I with a single sensory rod. Tarsi II, III and IV each with a blunt sensory rod. Phallic organs consisting of two curved genital stylets and a pointed sclerotized aedeagus. Ventral setation of body as in Fig. 5. In genito-anal region there are 5 pairs of setae arranged as follows:—3 pairs primary genital setae, a single pair of ventral setae, and anterior to these a pair of anterior ventral setae. Dimensions of idiosoma shown in Table 1.

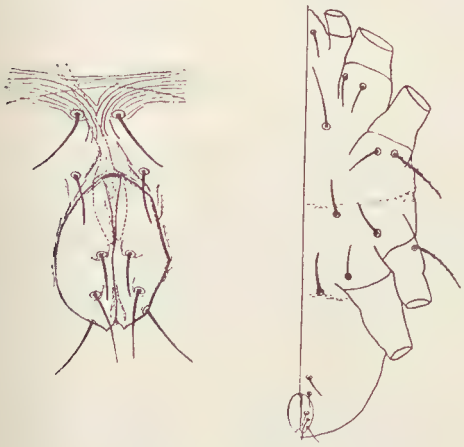

FIG. 5.—Ventral setation of male.

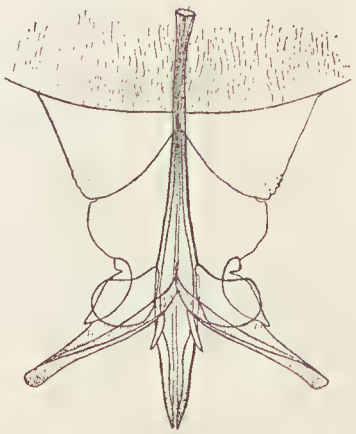

FIG. 7.—Aedeagus.

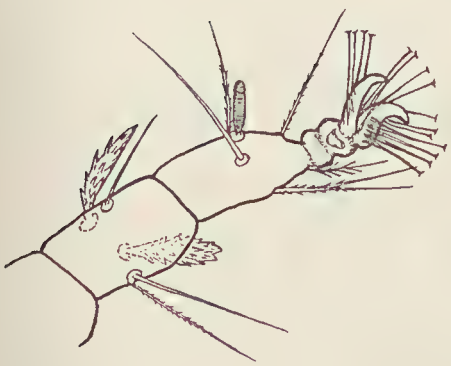

FIG. 6.—Tibia and Tarsus III of male.

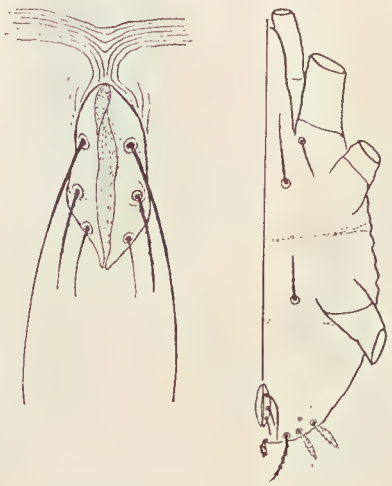

FIG. 8.—Ventral setation of larva.

Larva.

Similar to female but dorso-lateral foliaceous setae on both prodosoma and hysterosoma more pointed. Last four palmate setae on dorsum in a straight line. Caudum with only four pairs of ciliated flagellate setae and without foliaceous setae between these. Fifth segnemt of palpus bearing distally a blunt sensory rod and only one curved setae; only two tactile setae along length of segment. Fourth segment with spur reaching tip of segment five and bearing only two tactile setae. Peritreme not protruding ending in simple hook. Legs, 6, short and stubby. Tarsus I with only one sensory rod. Tibia I and Tarsus II each with single sensory rod. Ventral setation of body as in Fig. 8. At caudal end four pairs of setae, three pairs of which are foliaceous and one pair of coarsly ciliated setae. Genito-anal region with three pairs of primary genital setae. Dimensions of idiosoma shown in Table 1.

Protonymph.

Dorso-lateral setae of similar shape to those in larva. Last four palmate setae on dorsum arranged as in female. Caudum with five pairs of long ciliated flagellate setae of which outer pair are shortest. Small foliaceous setae between the long caudal setae as in female. Palpi and peritremes as in adults. Legs 8, Tarsus I with single sensory rod as in larva. Ventral setation of body as in Fig. 9. Genital region with four pairs of setae, of which three pairs are primary genital setae and anterior to these a pair of medio-ventral setae. Dimensions of idiosoma shown in Table .1

Deutonymph.

May be distinguished from protonymph by presence of two sensory rods on Tarsus I, and from the female by size and ventral setation (Fig. 10). In the genital region there are five pairs of setae, i.e., a pair of mediolateral setae additional to those of the protonymph. Dimensions of idiosoma shown in Table 1.

Tritonymph.

Similar to deutonymph except for size and ventral setation (Fig. 11). In the genital region seven pairs of setae, i.e., two pairs of secondary genital setae anterior to the primary genital setae in addition to those of the deutonymph. Dimensions of idiosoma shown in Table 1.

Holotype female and allotype male—Mt. Wellington (c. 335m), Tasmania 10.VIII.61 on *Bedfordia salicina* D.C. (Compositae), in Australian National Insect Collection, Canberra, A.C.T.

Paratypes—9 males, 16 females, 8 larvae, 10 nymphs, Mt. Wellington, Tasmania 10.VIII.61 and 15.VIII.61 on *Bedfordia salicina* D.C. in Australian National Insect Collection, Canberra, A.C.T., South Australian Museum, Adelaide, British Museum (Natural History), London, and Department of Agriculture, Hobart.

Material Examined—In addition to the type material listed above, the following specimens were examined:—

Tasmania. Grevillea robusta, Cunn. (Proteaceae), Hobart, Tas. 13.XII.57 (larva): *Notelaea ligustrina*, Vent. (Oleaceae), Hayes, Tas. 20.II.62 (nymph); *Leucopogon parviflorus* (Andr.) Lindl. (Epacridaceae), Nubeena, Tas. 22.III.63 (nymph); *Bedfordia salicina* D.C., Mt. Wellington, Tas. 10.VIII.61 and 15.VIII.61 (8 females, 26 nymphs); *Callitris tasmanica* (Benth) B. & S. Cupressaceae), Orford 24.VII.63 (2 females, 1 nymph); *Acacia dealbata* Link. (Leguminosae), Hayes, Tasmania 19.IX.63 (female).

N.S.W. Galled twig, Privet, Sydney, N.S.W. Oct. 1916; Privet, Mosman, N.S.W. 7.VII.34 and 8.VIII.34; Eucalypt with apiomorpha gall, Boomi, N.S.W. 16.VIII.34 (3 slides); Cypress pine, Castle Hill, N.S.W. 23.VIII.34; Guava fruit N.S.W. 26.IV.55.

TABLE 1.

Table of measurements of *Tuckerella flabellifera*.

Stage	No. specimens examined	Size of Idiosoma (μ)				No. pairs setae in Genito-anal Region
		Length		Greatest Width		
		Range	Mean	Range	Mean	
Larva	8	210-225	214	135-180	153	3
Protonymph	14	235-280	265	150-200	180	4
Deutonymph	13	280-335	311	170-215	199	5
Titronymph	5	325-360	350	215-240	229	7
Adult:						
Male	12	290-340	312	175-210	196	5
Female	25	355-465	403	270-300	260	9

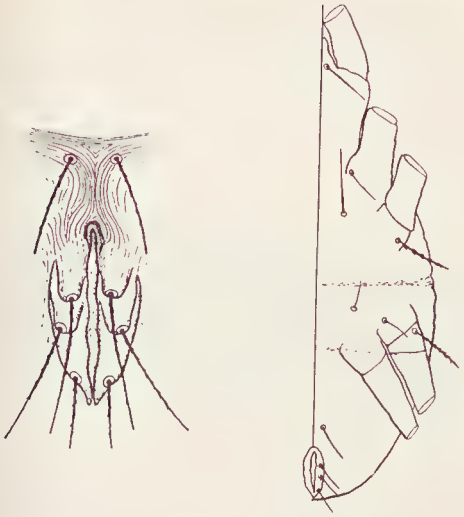

FIG. 9.—Ventral setation of protonymph.

DISCUSSION

Females of *T. flabellifera* are intermediate between *T. ornata* (Tucker) and *T. pavoniformis* (Ewing) in that they have five pairs of long caudal setae as in the former species but the last four palmate setae on the dorsum are similar to those in the latter species.

Males of *T. flabellifera* and the male of *T. spechtae* Womersley (previously designated as a female) have a single blunt sensory rod on Tarsi III and IV thus showing similarities between the males of the family Tuckerellidae and those of the related tetranychoid family Linotetranidae.

On the basis of measurements and ventral setation, the male of *T. flabellifera* appears to have only one nymphal stage, whereas the female has three. Even though the occurrence of a titronymphal stage in a tetranychoid mite may be unusual, no other interpretation could be placed on the data since analysis showed that the differences in size between deutonymphs (with 5 pairs of genital setae) tritonymphs (with 7 pairs of genital setae) and adult females (with 9 pairs of genital setae) were highly significant.

In 1940 Womersley erected the genus *Tuckerella* for the species *Tenuipalpus ornatus* described by Tucker from South Africa. In his paper Womersley figured and described a mite which he identified as *Tuckerella ornata* (Tucker). Baker & Pritchard (1953) considered that this was a misidentification for *T. pavoniformis* (Ewing). This opinion was apparently based on Womersley's figure which was of a mite with six pairs of long caudal setae and with the inner pair of the last four dorsal hysterosomals smaller and posterior to the outer pair. These characters would justify placement in *pavoniformis*.

In his description however, Womersley had stated that the caudum had "a tuft of 10-12 ciliated setae".

Since the numbers of caudal setae have been considered as diagnostic characters for separation of the known species of the genus, an effort was made to obtain the material identified by Womersley.

Seven slides were located covering all the localities and hosts listed by Womersley. Only two of the slides were of adult females, the remainder being various nymphal stages. All of these specimens had only five pairs of caudal setae. Since Womersley did not list the number of specimens he examined, it is not possible to say whether all the material has been re-examined. There was, however, one female which was of the size given by Womersley.

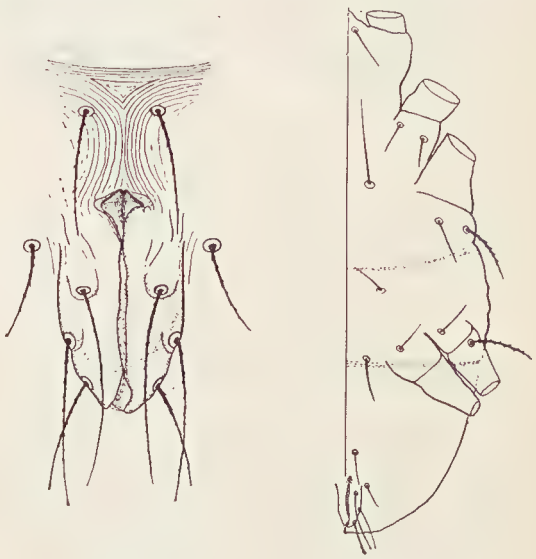

FIG. 10.—Ventral setation of deutonymph.

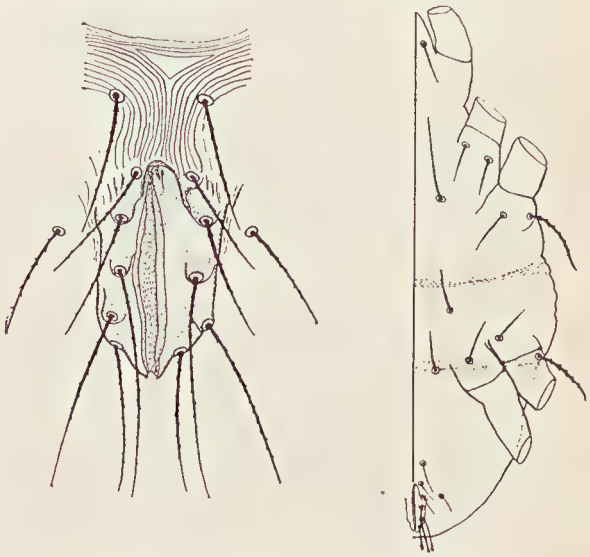

FIG. 11.—Ventral setation of tritonymph.

Since none of the specimens on these slides had six pairs of caudal setae it is most likely that Womersley was in error in his drawing, and this subsequently resulted in Baker & Pritchard considering that the specimens were *pavoniformis* (Ewing).

The specimens on the seven slides originally identified by Womersley as *T. ornata* (Tucker) are however, neither *ornata* nor *pavoniformis*, but are conspecific with the new species described herein.

It is doubtful therefore whether there is a valid record of *pavoniformis* from Australia and further more the host records for this species on eucalyptus, cypress pine, and privet, in Australia should be deleted (Baker & Pritchard (1953) also listed citrus as a further host attributing it to Womersley, but there is no mention of this host in Womersley's list).

ACKNOWLEDGMENTS

Thanks are due to the Trustees of the South Australian Museum, Adelaide, and to Mr. S. L. Allman, Chief Entomologist, New South Wales Department of Agriculture, Sydney, for the loan of slide material.

Messrs. K. A. Pickett and P. J. Tracey, Technical Officers, made a number of the field collections.

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OBSERVATIONS ON SOME TASMANIAN FISHES: PART XII

By

E. O. G. Scott

(With one text figure)

ABSTRACT

Two species are added to the Tasmanian list: *Parequula melbournensis* (Castelnau), 1872 [Gerridae]; *Neoodax radiatus* (Quoy & Gaimard), 1835 [Neoodacidae] (the specimen exhibiting variation in formula and in shape of dorsal). *Apogon lempriere* Johnston, 1883 [Apogonidae], apparently lost sight of since publication, is redescribed and figured: it is referred, with some reservation, to *Vincentia Castelnau,* 1872, the status of which *vis-a-vis Gronovichthys* Whitley, 1930 is discussed. Examination of a sample of 7 females of *Syngnathus curtirostris* Castelnau, 1872 [Syngnathidae] yields some proportional values extending the ranges recorded in the conspectus of local syngnathids (Scott, 1961), and provides some information on relative rates of growth of the various morphological segments of the antero-posterior axis: variations in body ridges and in colour pattern in this sample are recorded, and a summary is given of a study of coloration in another specimen. The fifth recorded example of *Syngnathus tuckeri* Scott, 1942 [Syngnathidae] is noted, and some relative growth rates in this species are tabulated: new extremes of size and proportion, lying outside those of the conspectus, are reported.

Keys are provided covering the Tasmanian members of the families Neoodacidae, Apogonidae.

INTRODUCTION

This paper follows the general plan of others in the series. The symbols *Ls, Lt* denote standard length, total length, respectively: *TLs, TLt* signify thousandths of standard, of total, length. All linear dimensions are in millimetres, the name of the unit commonly being omitted.

Family Syngnathidae

Genus SYNGNATHUS Linné, 1758

Syngnathus curtirostris Castelnau, 1872

Syngnathus curtirostris Castelnau, 1872, *Proc. Zool. Acclim. Soc. Vict.,* 1: 243. Type locality: St Vincent's Gulf, South Australia.

Syngnathus curtirostris Castelnau. McCulloch & Waite, 1918, *Rec. S. Aust. Mus.,* I, 1: 39; pl. V, fig. 1. McCulloch, 1929, *Mem. Aust. Mus.,* V, 1: 86. Munro, 1958, Handbk Aust. Fish.: 82, fig. 569 [instalment No. 20 in *Fisheries Newsletter,* XVII, 2, February 1958: 18, fig. 569].

Low Head specimen.—A female specimen, *Ls* 139.7, *Lt* 142.8, obtained at Low Head, Dorset, Tasmania by Miss A. Mather has been noticed earlier in these Observations (1953: 150), and attention has since been called (1961: 62) to the non-inclusion of Tasmania among the States recorded for this species in the Handbook (Munro, 1958: 82). Some observations on the coloration and color-pattern of this individual are made below.

Clarence Point sample.—Using a handnet among eel-grass Mr R. H. Green secured in January 1962 a series of 7 examples—(*a*)-(*g*), *Ls* 56.2, 76.1, 87.1, 89.1, 93.5, 97.0, 97.9; *Lt* 58.4, 78.0, 89.1, 91.1, 95.6, 99.0, 100.0, respectively—at Clarence Point, Devon. None show any sign of brood pouch. Though rather small numerically the sample yields some interesting comparative data. Enumeration of counts, measurements and non-metrical features here given are set out in order of asscending magnitude of total length of fish.

The sample includes also 3 specimens of *Syngathus phillipi* Lucas, 1891, *Ls* 73.3, 83.8, 88.0; *Lt* 75.1, 86.0, 90.1.

Extension of conspectus values.—A conspectus of Tasmanian syngathids (Scott, 1961) provides, as the first 8 entries for each species, the minimum and maximum values, as recorded in the literature, for a count or body proportion. For several characters the present material extends a recorded value to stand now as follows: caudal annuli 42-47 (in conspectus 42-44); eye in snout 1.8-3.0 (1.8-2.1); head in trunk 2.4-3.5 (2.9-3.5); trunk in tail 2.2-2.8 (2.2-2.4).

The reason for the distinctly smaller eye in our material remains obscure—especially in view of the facts, first, that our specimens are smaller than those of those previously reported upon (Waite & Hale's 2 males, 2 females 125-164), and, secondly, that the published ratios take account of a Tasmanian example (from Low Head; *Lt* 142.8). All our values for head in trunk (2.4-2.6) and for trunk in tail (2.5-2.8) also stand outside the accepted ranges.

In giving in the conspectus snout in head as 2.5-2.7, the 'three times' of the original (two-sentence) notice of the species (1872 *b*) was overlooked.

Lt.—The estimated standard deviation of a random sample of 7 items from a normal population, the sample having a range equal to the *Lt* range of the present series (41.6) is 15.38 [a convenient table is given by Lindley & Miller (1953)]: the calculated standard deviation (unadjusted, using *n*) of Mr Green's collection is 13.66. These

values are not inconsistent with the hypothesis that that we are here randomly sampling a normal population of total lengths, a hypothesis that applies with equal force to the two populations, number of dorsal rays, number of caudal annuli, dealt with below. For *Lt*, *V* (unadjusted) is 15.6, which seems rather unexpectedly high for members of a single age-group: it is possible specimens (*c*)-(*g*) with *Lt*-range 10.9, and *V* 4.50, are coeval, with the 2 other individuals of a somewhat different age, or ages.

Dorsal rays, dorsal base.—Rays number 20, 23, 24, 20, 23, 22, 20; the range being identical with that recorded for the species in the conspectus: σ, estimated for normal population, calculated, 1.479, 1.414. Length of dorsal base, which like number of rays, exhibits no apparent correlation with *Lt* (see Table I) has estimated, calculated σ 1.109, 1.056. No correlation subsists in this small sample between base-length and ray number.

Other fins.—The minute anal appears regularly to have 3 rays. P. 10-11. Waite & Hale (1921: 300) give C.10; but our specimens have 5 or 6 rays, of which most, or all, are bifurcate.

Annuli.—All these fish have 18 trunk annuli (recorded range 18-19). Tail annuli number 44, 44, 45, 45, 46, 45, 44 (all exceeding the previously known maximum): with estimated, calculated σ 0.740, 0.700, a normally distributed population is suggested. No correlation is apparent between number of caudal rings and overall size.

Dimensions and proportions.—Table I sets out, for 8 important dimensions, first, the absolute extension along anteroposterior axis of fish as measured (mm); secondly, this value as estimated from the equation of regression of relevant region (*Y*) on total length (*X*); thirdly, the relative magnitude of the dimension (as measured), expressed as thousandths of total length (*TLt*); fourthly, the equation of regression of *Y* on *X*, together with its *t*-value; fifthly, the correlation coefficient of *Y* and *X*, both *r* and *z* being recorded (Simpson & Roe, 1939). Some comments on the table follow.

(i). The correlation of *Y* and *X* is seen to be exceptionally high: for one entry, snout, $P < 0.02$ (about 0.011); for the 7 remaining entries $P < 0.01$, indeed, for 4 of them, head, trunk, preanal region, tail, $\mathbf{P} < 0.001$. The sample thus affords striking evidence of the validity and reliability (at least for this species, this sex, and the relevant size-range) of current taxonomic practice in employing as systematic criteria ratios based on body regions here dealt with. Not unexpectedly, the larger dimensions, measurable with relatively greater accuracy, yield the larger coefficients, *z* exceeding 2 only in head and regions longer than it.

(ii). The absolute magnitudes estimated from the regression equations are published alongside the measured magnitudes with the feeling that the potential systematic value of such equations is perhaps not as widely realized as it might be. In the writer's experience it has been found that with data of this type their predictive value is such (and this among various groups of fish) as to permit of the making of interpolations, and in general of at least small-scale extrapolations, with a high measure of confidence. In not a few instances they afford reliable, at times surprisingly sensitive, criteria for specific, subspecific or sex distinction. As an indication of their accuracy of estimation—a good general idea of which may be gained directly from the table—the following summary is not without interest. With 8 dimensions in ascending order of size, the ranges (in parentheses, means) of the divergences between measured and estimated values are, in mm.: 0-0.1 (0.04), 0-0.3 (0.14), 0.1-0.4 (0.19), 0-0.4 (0.21), 0-0.3 (0.11), 0-0.2 (0.14), 0-0.2 (0.10), 0-0.2 (0.09); overall 0.4 (0.15). Expressed as percentages these quantities are: 0-9.1 (3.42), 0-9.1 (4.25), 2.3-10.5 (5.03), 0-8.0 (3.46), 0-3.3 (1.33), 0-0.9 (0.51), 0-0.7 (0.35), 0-0.5 (0.18); overall, 0-10.5 (2.65)—the high percentage differences among the smaller dimensions being of course largely attributable to the relative coarseness of the measuring technique here (in the case of the eye, a difference of one unit of measurement, *i.e.*, one-tenth of a millimetre, represents up to 10% of total dimension); in no one of the largest 3 dimensions does the maximum divergence for any specimen amount to 1 mm.

(iii). It will be seen that the relative length of the tail increases with the increase in size of fish, the *TLt* values rising unequivocally across the table from left to right from 640 to 659. (Campare data given below for *S. tuckeri*, Table III and discussion). A breakdown of the preanal region into its primary components of head and trunk reveals both of these as exhibiting a tolerably clear trend of decrease in *TLt* from the smallest to the largest specimen. A secondary breakdown of head to its successive components of snout, eye, postorbital head fails to yield certain evidence in these elements of a similar decrease (or an increase); the most suggestive sequence of entries being that for eye. Further light is thrown on the general problem of regional growth among the members of this sample by a consideration of percentage growth increments.

Percentage length increments.—Table II gives, for each of the 8 morphological regions dealt with in Table I: in the first line the percentage increase in length over specimen (*a*) of each of specimens (*b*)-(*g*); in the second line this value as estimated from the regression equation; in the third line the (actual) percentage increase relative to the percentage increase in *Lt*, the latter being taken as unity. The procedure here adopted in calculating the increments, namely, in terms of the increase, in turn, of each of specimens (*b*)-(*g*) over (*a*)—which has the undesirable effect of attaching undue weight to the dimensions of (*a*)—derives from the fact that there is not invariably associated with an increase in *Lt* an increase in the relevant region (see first lines of Table I). In the case of the two main regions, in which no such problem arises, calculations in which the obvious course of determining values in turn for (*b*)—(*a*), (*c*)—(*b*) . . . (*g*)—(*f*) yield results not differing greatly from those entered in Table II; the preanal percentage increase in length relative to that of *Lt* as unity having an arithmetic mean of 0.837 (geometric mean 0.827), and that for tail 1.093 (1.090).

TABLE I

Syngnathus curtirostris Castelnau, 1871. Seven specimens from Clarence Point, Devon, Tasmania. Anteroposterior lengths of 8 specified regions—absolute (mm), first, as measured, secondly, as estimated from regression equation (recorded, with indication of significance) of relevant region (*Y*) on total length, *Lt* (*X*); relative, as thousandths of total length, *TLt*: also correlation of *X* and *Y*

Region (*Y*)		Specimen *Lt* (mm) (*X*)							Correlation of *X* and *Y*		Regression of region (*Y*) on *Lt* (*X*)	
		(*a*) 58.4	(*b*) 78.0	(*c*) 89.1	(*d*) 91.1	(*e*) 95.6	(*f*) 99.0	(*g*) 100.0	*r*	*z*	Equation	*t*
Snout	Measured	2.6	3.0	3.3	3.9	3.9	3.9	3.9	0.870**	1.334		
	Estimated	2.5	3.2	3.6	3.6	3.8	3.9	3.9			$Y = 0.03437\,X + 0.50$	6.26**
	TLt	45	38	37	43	41	39	39				
Eye	Measured	1.0	1.1	1.3	1.4	1.3	1.4	1.4				
	Estimated	1.0	1.2	1.3	1.3	1.4	1.4	1.4	0.940**	1.736	$Y = 0.01355\,X + 0.37$	7.05**
	TLt	17	14	15	15	14	14	14				
Postorbital head	Measured	2.4	3.8	4.1	3.9	4.3	4.1	4.3				
	Estimated	2.6	3.4	3.9	4.0	4.2	4.3	4.4	0.949**	1.819	$Y = 0.04240\,X + 0.14$	6.10**
	TLt	41	49	46	43	45	41	43				
Head	Measured	6.0	7.9	8.7	9.2	9.3	9.4	9.6				
	Estimated	6.1	7.8	8.7	8.9	9.3	9.6	9.7	0.981**	2.321	$Y = 0.08476\,X + 1.19$	11.36**
	TLt	103	101	98	101	97	95	96				
Trunk	Measured	15.0	19.6	22.2	22.3	23.5	24.5	24.5				
	Estimated	15.0	19.5	22.1	22.5	23.6	24.3	24.6	0.999**	3.913	$Y = 0.2294\,X + 1.63$	74.00**
	TLt	259	251	249	245	246	248	245				
Preanal region	Measured	21.0	27.5	30.9	31.5	32.8	33.9	34.1				
	Estimated	21.1	27.3	30.8	31.4	32.9	33.9	34.2	0.981**	2.324	$Y = 0.3150\,X + 2.73$	86.17**
	TLt	360	353	347	346	343	342	341				
Tail	Measured	37.4	50.5	58.2	59.6	62.8	65.1	65.9				
	Estimated	37.2	50.6	58.2	59.6	62.7	65.0	65.8	0.981**	2.316	$Y = 0.6842\,X - 2.67$	45.92**
	TLt	640	647	653	654	657	658	659				
Dorsal base	Measured	3.9	5.0	6.5	6.6	6.9	6.7	6.9				
	Estimated	3.9	5.4	6.2	6.4	6.7	7.0	7.0	0.950**	1.828	$Y = 0.7674\,X - 0.63$	9.79**
	TLt	67	64	73	72	72	68	69				

TABLE II

Syngnathus curtirostris Castelnau, 1872. Seven specimens from Clarence Point, Devon, Tasmania. Percentage increase of length of each of 6 specimens (*b*)-(*g*) (*Lt* 78.0-100 mm) on specimen (*a*) (*Lt* 58.4) in respect of *Lt* and of 8 morphological regions along anteroposterior axis of fish. For each region there is entered: first, the actual percentage increase in length; secondly, this magnitude as estimated from regression equation (recorded, with indication of significance) of region (*Y*) on total length, *Lt* (*X*); thirdly, actual percentage increase relative to that of *Lt* as unity

Region (*Y*)		Specimen (*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	Arithmetic mean (Geometric mean)	Regression of region (*Y*) on *Lt* (*X*) Equation	*t*
Snout	Actual	15.4	26.9	50.0	50.0	50.0	50.0	40.36 (37.06)		
	Estimated	17.5	35.5	38.7	46.0	51.5	53.4	40.63 (38.07)	$Y = 0.9447\,X - 14.18$	3.33*
	Relative to *Lt* value as unity	0.46	0.51	0.89	0.78	0.72	0.70	0.678 (0.661)		
Eye	Actual	10.0	30.0	40.0	30.0	40.0	40.0	31.67 (28.84)		
	Estimated	13.8	27.8	30.4	36.1	39.2	41.8	31.50 (29.71)	$Y = 0.7394\,X - 11.04$	3.73*
	Relative to *Lt* value as unity	0.30	0.57	0.71	0.47	0.58	0.56	0.532 (0.514)		
Postorbital head	Actual	58.3	70.8	62.5	70.8	70.8	79.2	68.75 (68.42)		
	Estimated	58.0	66.5	68.0	71.4	73.9	74.9	68.77 (68.53)	$Y = 0.4426\,X + 43.19$	3.10*
	Relative to *Lt* value as unity	1.74	1.35	1.12	1.11	1.02	1.11	1.241 (1.220)		
Head	Actual	31.7	45.0	53.3	55.0	56.7	60.0	50.27 (49.22)		
	Estimated	32.7	46.5	49.0	54.6	58.8	60.1	50.28 (49.20)	$Y = 0.7289\,X + 8.18$	8.09**
	Relative to *Lt* value as unity	0.94	0.86	0.95	0.86	0.82	0.84	0.879 (0.877)		
Trunk	Actual	30.7	48.0	48.7	56.7	63.3	63.3	51.78 (50.34)		
	Estimated	30.5	47.2	50.2	57.0	62.1	63.6	51.80 (50.33)	$Y = 0.8826\,X + 0.80$	25.97**
	Relative to *Lt* value as unity	0.91	0.91	0.87	0.89	0.91	0.89	0.898 (0.897)		
Preanal region	Actual	31.0	47.1	50.0	56.2	61.4	62.4	51.35 (50.05)		
	Estimated	31.3	47.2	50.1	56.5	61.4	62.9	51.57 (50.40)	$Y = 0.8383\,X + 3.15$	169.69**
	Relative to *Lt* value as unity	0.92	0.90	0.89	0.88	0.88	0.88	0.892 (0.892)		
Tail	Actual	35.0	55.6	59.4	67.9	74.1	76.2	61.36 (59.49)		
	Estimated	35.0	55.7	59.4	67.8	74.2	76.1	61.37 (61.38)	$Y = 1.0907\,X - 1.64$	285.95**
	Relative to *Lt* value as unity	1.04	1.06	1.06	1.07	1.07	1.07	1.060 (1.060)		
Dorsal base	Actual	28.2	67.7	69.2	76.9	71.8	76.9	64.96 (61.72)		
	Estimated	35.0	58.5	62.8	72.3	79.5	82.0	65.01 (62.67)	$Y = 1.2374\,X - 6.51$	5.22**
	Relative to *Lt* value as unity	0.84	1.27	1.24	1.21	1.03	1.08	1.111 (1.110)		
Total length	Actual	33.6	52.6	56.0	63.7	69.5	71.2	57.76 (56.10)	—	—

It will be observed that, while among the smaller body regions there is some considerable measure of irregularity in the pattern presented by these values, even to the extent of the occurrence, in some instances, of entries in the first line that constitute a local reversal of the general trend of increase, proceeding from left to right, there is, in the case of the head and of larger regions, a very satisfactory overall regularity: to make possible a precise formulation of this consistency the regression equations of the percentage length-increments of the several regions (*Y*) on corresponding increments of *Lt* (*X*) have been calculated, and are recorded in the table; and the estimated percentage increments estimated from these equations are given in the second line, for each region, for comparison with the values as found, entered in the first line.

As in the preceding table, the extremely close correspondence between the measured and predicted entries of the first and second lines in all major regions is noteworthy; and the suggestion is here repeated that such reliability of estimation is surely not without useful systematic application. In both tables the tendency of the value of *t* to increase, *pari passu*, with increase in magnitude of body-segment studied is of a striking, almost textbook character: [extremely high *t*-values associated in the present table with two of the equations (those for the two primary moities of total anterposterior extension of the fish) are probably in part attributable to the fact that we are here plotting, not primary length-measurements, but percentage increments, and treating these as basic data].

Inspection of the column of means (the discussion is based primarily on the arithmetic means: the geometric means, given in parentheses, follow the same sequence) reveals that for postorbital head, dorsal base, tail the relative increase in length exceeds that for *Lt*, while for 5 other dimensions it is less than for *Lt*. It is possible the divergences from unity of all the entries in the third lines point to genuine variations—at any rate in the indicated sense (in excess or defect of equality with the *Lt* mean), if not of actual magnitude—in the percentage increase of relevant region as compared with percentage increase of *Lt* that examination of further material may satisfactorily establish. However, data at hand for the smaller body-regions are at once too few and too erratic to permit of the drawing of any definite conclusions: on making tests of the significance of the regression coefficients of the equations for region on *Lt* it is found that for the three recognized segments of the head coupled severally with the head as a whole the differences fall below the level of satisfactory statistical significance (for snout-head, eye-head, postorbital head-head $t = 0.62, 0.05, 1.56$, respectively). Again, for dorsal base-head $t = 1.88$. On the other hand, significant differences between the regression coefficients are encountered in these pairs: head-trunk ($t = 9.99^{**}$), preanal length-tail ($t = 2.86^{*}$).

The overall picture of relative regional growth that emerges, then, is this. Percentage increase of postanal extension as a whole significantly exceeds that of total preanal extension; further, there is a strong suggestion that the sequence head, trunk, tail exhibits a gradient of percentage length-increment, rising caudad. For the segments of the head the data are statistically inconclusive, but as far as the means may be accepted as provisional pointers the sequence of relative increases arranged in ascending order of magnitude does not parallel the morphological sequence of regions—snout, eye, postorbital having intermediate, least, greatest values, respectively. Dorsal base, which is chiefly postanal, appears to follow the high relative increase characteristic of the tail as a whole.

The employment of such statistical procedures as those involved in the above analyses has somewhat the appearance of the use of a sledge-hammer to crack a nut: the conducting of the investigation at this level has, however, seemed worth while, inasmuch as there is thus rendered apparent, to a degree scarcely otherwise possible, the clarity and quite remarkable precision with which, even from very small samples, same basic features of the pattern of growth in these fish can be apprehended and formulated; the models thus arrived at lending themselves to systematically useful specification and prediction of body-form.

Other proportions.—The maximum width of the head is equal to, slightly greater than, less than, the maximum depth of head in 2, 3, 2 individuals; the former dimension being 3.1-3.6, $\bar{x}$ 3.28, the latter 3.0-3.8, $\bar{x}$ 3.23, in length of head. One specimen (*c*) has head, exceptionally, 1.2 times as deep as wide. The maximum depth of the body, on the other hand, consistently exceeds its maximum width (as Waite & Hale (1921: 300) also found); the former dimension being 2.5-3.2, $\bar{x}$ 2.83, the latter 3.1-4.0, $\bar{x}$ 3.47 in length of head. At middle of tail the width is 4.8-7.3, $\bar{x}$ 5.95, the depth is 4.1-8.6, $\bar{x}$ 5.75, in length of head.

Body ridges.—Some minor variations occur in the location of the free end, on the two sides of the fish, of the upper trunk (TU), median trunk (TM), and upper caudal (CU) ridges. Expressed in the terms of the anterposterior extent of one trunk or caudal annulus, the differences are: TU 0 (1 specimen), 0.1 (4), 0.2 (1), 0.5 (1); TM 0 (4), 0.1 (2), 0.2 (1); CU 0 (2), 0.2 (1), 0.3 (3), 1.0 (1)—the overall mean being 0.11. Pooling, for each type of ridge, the 14 observations for the 7 specimens, and specifying the point of termination (or of origin; CU) as a decimal of the length of the relevant annulus (with front of ring as origin), we find TU ends at 0.5 (1), 0.6 (1), 0.7 (1), 0.8 (4), 0.9 (3), end (4) of third caudal; TM ends at 0.8 (1), end (8) of last trunk and at 0.1 (4), 0.2 (1) of first caudal; CU originates at 0.4 (5), 0.6 (2), 0.7 (2), 0.9 (2) of last trunk and at 0.1 (2), 0.4 (1) of first caudal. Only in TU, therefore, is an end-point restricted to the one annulus—a point not without systematic interest in view of the frequent specification in this context in descriptions of Australian syngathids of a single annulus.

In (*f*) CU is subcontinuous with an anomalous lateral ridge extending forward along the trunk, above TM, for about 11 (left) about 10½ (right) annuli.

Cephalic ridges.—Head with numerous striae, including: on dorsum behind eyes a whorled series (this region also heavily pitted); on small trapezoidal occipital plate about a dozen main striae running out from median ridge; many, the anterior subvertical, on side of head above operculum; a set between anterior opercular border and orbit; two rosettes and several longitudinal lines on side of snout. Interorbital honeycombed and pitted. Operculum without transverse ridge, with 30-40 main radial striae.

Rostral crest low: back to level of end of expanded snout-tip very low, its free margin here virtually horizontal; behind this rising tolerably evenly (with aid of lens, profile seen to comprise 2 segments, the posterior rather shorter, steeper); minute, but constant, notch at level of nostril; traceable back to about level of anterior $\frac{1}{3}$ of eye, lapsing in this vicinity into a forwardly-directed triangular tongue, somewhat elevated, the lateral borders of which may be defined by distinct minute ridges, and along the middle of which the line of the crest may be continued as a minute ridge. Supraorbital ridges originating near base of rostral crest, at, or a trifle in advance of, level of nostril; extending feebly behind eye to delimit laterally dorsum of head here, reaching exceptionally to level of middle of operculum (*i.e.*, about $1\frac{1}{2}$ eye-diameter beyond orbit), but commonly lapsing, or becoming indistinguishable from striae, at about $\frac{1}{3}$ of this distance. A feeble median ridge (continuous in all except (*b*)) originating at level of posterior orbital border (or, (*c*), $\frac{1}{2}$ eye-diameter behind this); extending to, or virtually to, anterior border of small trapezoidal occipital plate, not quite continuous with its ridge, the latter continuous behind with the nuchal ridge, which is commonly about $\frac{2}{3}$ (in (*c*), 1) eye-diameter long: all these ridges rather feeble, the system best developed and most stable posteriorly. Between eye and inflated, striated region of operculum 4 ridges: 1 delimiting whole of upper and of short subvertical anterior border of operculum; 1, about $\frac{1}{3}$ eye-diameter long, running obliquely backwards and upwards across upper part of the flattened lobate beginning of operculum; 1 running from 4 o'clock on orbit (left side viewed) in an upwardly convex arc to operculum; 1, the longest, running, more or less horizontally, from 3 o'clock on orbit, to cease hard against hinder, more nearly horizontal segment of upper opercular border. Shallowly sigmoid ridge from top of upper lip to nostril.

Coloration and color pattern, Clarence Point sample.—For a sample taken at the one time and homogeneous for sex there is considerable diversity of coloration and color pattern: part of this, no doubt, is a question of size, but a good deal would appear to be individual. The fully adult pattern of the Low Head example, dealt with later, is not found in any of these specimens, of which one only, (*b*), shows any clear indication of broad cross bars, and one only, (*f*), has the 'festoon' marking along the mediolateral trunk ridge. The general ground color varies from almost black through dark and medium brown to light brown and grey, the sequence of specimens being (*a*), (*g*), (*c*), (*b*), (*d*), (*e*), (*f*); however, on dorsal surface (*e*) is darker than any other individual.

(*i*) *Head.*—Dorsal surface behind eyes lighter than early trunk, from whitish through pale greyish to fawn, immaculate, (*b*), (*c*), (*d*), (*f*), or with small brown splashes, (*e*), (*g*), or punctulations and reticulations, (*a*). Lateral surface from behind eye (which occupies from rather more than half space between dorsal and ventral profiles, (*g*), to virtually the whole, (*a*)) to anterior $\frac{1}{6}$-$\frac{1}{3}$ of operculum carries an extension of light area of dorsum, from which it is usually separated (not in (*a*), (*e*)) by a more or less well-defined streak or line of brown; this region, which may contain some small darker markings, is delimited from cheek below level of inferior orbital border (which, except in (*e*), is somewhat, usually notably, darker) by dark line or row of reddish brown blotches. Operculum light colored (with or without darker markings) in anterior $\frac{1}{6}$-$\frac{1}{3}$ only, except in (*e*), in which about upper $\frac{1}{3}$ is fawn, the rest whitish: along posterior and inferior margins an arc of minute spaced blackish dots, in (*b*), 5-6 dots, (*e*), 3-4, (*g*), 8: in (*c*), (*d*) about 8 short spoke-like brown lines bordering operculum behind, these being represented in (*e*), (*g*) by a few indistinct vermiculations. Except in (*a*), snout lighter than rest of head (quite apart from snout-size, the characteristic 'light-snouted' suffices to distinguish this species from *S. phillipi* in the same phial), ranging from ivory to very pale brown, the ventral surface usually the lightest, the darkest area on, and immediately flanking, the middorsal ridge; extreme tip usually paler. In (*b*), (*g*), 2 lines of dark brown (straight, except initially, just behind level of posterior border of orbit, where each presents a short arc, concave mesiad) run forward, following the converging mandibular ridges for $\frac{1}{2}$ length of snout; in (*e*) the line suffers an interruption in its anterior $\frac{1}{3}$, in (*c*) it is represented by a row of 7-8 dots, extending $\frac{1}{6}$ of snout; in (*f*) only part of the proximal arc is present, and the markings are absent in the others. In (*b*), (*c*) a row of 3 or 4 minute black dots runs external to marking just described. In the 4 larger specimens 2-3 reddish-brown spokes radiate from antero-inferior border of orbit.

(*ii*) *Trunk.*—Dorsal surface: in (*a*) uniformly dark brown, approaching black; in (*e*) black, quite different from (*a*), the black appearing as if present as a sort of encrustation on the brown substrate surface, of which some small patches are exposed, particularly laterally; in (*b*) midbrown, with 3, perhaps 4, darker bars, in others medium, or (*g*), darkish, brown, without bars; dark median stripe in (*d*) only; the sutures of the annuli marked, in (*f*), (*g*), by fine dark lines, in (*b*), (*c*) by small laterally placed light areas that become apparent on 1st annulus, (*b*), or on 5th, (*c*), and continue to increase in area and to throw inward longer prolongations that finally meet mesially. Lateral surface: in (*a*) as in dorsum; in other specimens the upper half more or less concolorous with the dorsal surface, the lower half usually somewhat lighter (in (*d*) sharp demarcation along whole TM ridge); in (*b*) partial, in (*c*) and (*f*) pronounced, rove-over of segmental division lines of dorsum; in (*e*) a double festoon of warm brown, one loop to an annulus, running closely above and below TM (better developed

below), and along inferior border of midbrown line, bulging up somewhat into each annulus; in (*g*) the decidedly lighter half abundantly punctulate and minutely vermiculate—dark bars noted on dorsum of (*b*) apparent also on this surface. Ventral surface: varies from black (*a*) through greyish and fawn to lightish brown, the anterior portion usually somewhat (in (*d*), (*e*) notably) lighter; a pair of minute lateral black spots may occur on each of the first few annuli, (*b*), or on most annuli, (*c*); lightbrown, chiefly longitudinal vermiculations may occur anteriorly, (*d*), or through most of the length (though best developed anteriorly) (*e*); in (*f*) the light vertical segmental lines of the lateral surface continue on to this surface, where they tend to assume a T-shape, the crosspiece along the inferolateral border, the main limb lying transversely—dark bars of (*b*) visible on this surface also.

(*iii*) *Tail.*—Ground color of all surfaces becomes lighter posteriorly (except in (*e*) in which the dark brown turns black caudad), the change most marked in posterior one-third, or more, tending to occur earliest on ventral surface (and most marked here, usually approaching, or, (*d*), becoming, pure gold), latest on dorsal; intersegmental lines generally well developed, better than on trunk, usually lighter anteriorly, darker (not in (*d*)) posteriorly, than their interspaces; commonly narrow near median line (tolerably broad in (*b*)), often expanding laterally to form patches (mostly subtriangular), which may give rise (if so, normally to an increasing extent caudad) to longitudinal segments lying along surface-junctions—in (*b*) indications of 9 dark bars, best seen on ventral surface.

(*iv*) *Fins.*—Dorsal: translucent, whitish, or pale yellow (in (*c*) light brown); rays, as often as not, more yellowish than membrane. Caudal: membrane yellowish or pale fawn in 3 larger individuals, light brown in 4 smaller; rays more or less uniform yellowish or light brown in (*a*)-(*d*), pale fawn in (*g*), lighter in central part of, (*e*), or in whole of, (*f*), basal half; except in (*a*), outer ray, above and below, spotted or banded with white, sometimes, (*d*), (*f*), (*g*), these, and one or two other rays, also with dark brown blotches; regularly tipped briefly white, or, (*f*), (*g*), pale, most noticeably so across central rays, except in (*e*), in which upper outer 2 rays are white in most of distal half. Pectoral: in (*a*) largely blackish, with lower ray (left) or 2 rays (right) partly silvery, and with some silver at bases of some other rays; in (*g*) largely silvery; in other specimens ranging, without marked differentiation between membrane and rays, from translucent to straw-coloured or pale golden.

Life coloration, Low Head specimen.—In the original record of Miss Mather's Low Head specimen, which added *S. curtirostris* to the Tasmanian list, it was stated (1953: 150): 'It is proposed to make the coloration and color pattern of this fish the subject of a separate paper.' The study referred to, which grew to rather unwieldly proportions, has not been published: most of the factual material and some of the discussion, much abbreviated, is presented below.

(*i*) *Ground coloration: description.*—Waite & Hale (1921) have provided an account (taking notice of well-marked sexual dimorphism) of the coloration and color pattern of preserved examples, but nothing appears to be recorded of the appearance in life. The living fish is a very beautiful object as the following notes, based on Miss Mather's female, make evident. Ground color of head: lateral surface medium brown, becoming darker on upper and lower borders of snout, the upturned tip of the lower jaw very dark, approaching black; upper half of operculum pinkish, lower half amber; dorsal surface dark brown, lightest on nape; ventral surface of snout rich dark amber, very dark at tip; rest of head golden brown. Ground color of trunk and tail: lateral surface warm mid-brown on trunk, somewhat darker on tail, rather lighter near end of tail than ventral surface there: dorsal surface of trunk somewhat darker than sides; dorsal surface of tail distally at least as dark as, perhaps a trifle darker than, its under surface: ventral surface golden orange, brightest, most golden near midline; around, and just in advance of, vent glowing ruby; tail with anterior one-third light brown darkening posteriorly, middle one-third medium brown, posterior one-third very dark brown. Head and tail somewhat translucent. (Color markings described separately below).

(*ii*) *Ground coloration: discussion.*—The depth of the ground color thus exhibits an anterposterior gradient, with a change of sense near the back of the head, from which point of inflection the general color progressively darkens, in the anterior section of the fish cephalad, in the posterior section caudad. The tone increment (alternatively, since in any one direction the anterposterior intervals along any of the four superficial body-planes are identical, the rate of change of tone) is, however, not constant, with the result that while, anteriorly, on the trunk, the ventral surface is lighter than the lateral, posteriorly, on the tail, it becomes darker than the lateral. Symbolic representation of the data serves to clarify and emphasize the relevant relationships and symmetries. Let *A, B, C* be, respectively, inferior, lateral, superior surfaces on the postcephalic region, and *a, b, c* the same, respectively, on the head; let x be the level of the point of change of sense, and y the level of the distal point of the system (with y_1 = base of caudal fin, y_2 = tip of snout); and let $>$ signify greater than in respect of depth of ground color. Then in combined trunk and tail we have:

$$(A, B, C)y_1 > (A, B, C)x \quad \ldots\ldots\ldots\ldots \quad (1a)$$
$$Cx > Bx > Ax \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2a)$$
$$Cy_1 > Ay_1 > By_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3a)$$
$$A\ (x—y_1) > B\ (x—y_1) > C\ (x—y_1) \quad (4a)$$

Also, if p is the darkest surface at a given point along the anterposterior axis, and q is either of the remaining surfaces,

$$(px—qx) > (py_1—qy_1) \quad \ldots\ldots\ldots\ldots \quad (5a)$$

As inequality (5a) suggests, differences at y_1 are small: indeed, (3a) represents only a majority judgment of three observers, one reading $Ay_1 > Cy_1 > By_1$. Neither version, it may be noted, is however, symmetrical with (2): though clearly it is possible, with other data, to have formal identity at the levels x and y with retention of the basic $A > B > C$ of inequality (4a).

In the head the position is somewhat more complex: since, in the first place, much of the snout is almost trihedral, and in advance of the eyes *c* disappears (or virtually disappears, being represented perhaps by a median ridge); and secondly, color markings are here so extensive as to render determination of the ground color in parts somewhat uncertain. With Y_3, the level of the posterior orbital margin, treated as a satisfactory estimate of Y_2 in C_2, the five propositions (1β)-(5β) symmetrical with (1α)-(5α) that are obtained on substitution of *a, b, c* for *A, B, C*, respectively, and of y_2 (or its estimate y_3) for y_1 are probably valid.

Satisfactorily to establish, or even adequately to analyse, the possible implications of these results would obviously necessitate the carrying out of an extensive investigation, covering a wide range of material and involving much experimental work. Several suggestive lines of inquiry followed, as far as available data permitted, in the unpublished paper already referred to are not, for lack of space, considered here. However, a brief comment on the significance of (4) can profitably be made. Two points may be noted: first, if instead of (3) as it now stands we had $(A, B, C)y = k$, to which condition (3α) actually approaches, then (4α) would be already determined, being merely a formal restatement of the conjunction of the supposed constant value at *y* and the statement of (2α); secondly, considered in isolation, however, the essentially gradual and even character of the color gradient in (4α) , while possibly of apatetic value [the possible significance of the ground colors and the various pattern-elements as factors in protective coloration was the subject of consideration in the unpublished study], might well be interpretable as a direct pigmentary expression of a general anteroposterial physiological acceleration (though it is noteworthy that in (4β) the tone-alteration, in *a* and *b*, while possibly also gradual is certainly in addition—a threshold phenomenon? —distally abrupt).

(*iii*) *Fins.*—Dorsal pale honey; rays scarcely darker than membrane. Anal minute, blotched longitudinally with brown. Pectoral pale golden; rays with red-brown streaks and dots. Caudal dark; rays distinctly darker than membrane.

(*iv*) *Chief pattern elements.*—The color pattern of Miss Mather's fish is highly complex (to a degree beyond that suggested by published accounts of this species): some suggestions towards its analysis are noted in subsequent sections. The chief elements involved include: broad cross-bars on head, trunk, tail (see (*vi*), below); segmental markings, largely in the form either of lines more or less completely coincident with the striae of the embossed shields of the annuli or of dark subcircular or ovoid spots, either occurring in isolation on the upper or lower half of the lateral surface, or, more frequently, being continuous, by isthmuses of varying tenuity, over both these regions, to which they may be confined, or beyond which they may extend—differentially, in respect both of area and form, along the anteroposterior axis—on to the ventral surface; longitudinal markings, best developed inferiorly; a variety of non-segmental discrete elements of diverse form, non-serial or serial (in the latter condition exhibiting, in some instances, marked gradients in respect of size and/or intensity); a complex series of cephalic markings, including circumocular spokes and their lighter interspaces, light and dark spots, vermiculations, punctulations, and cloudings resulting from an aggregation of pigment the resolution of which into its discrete elements is beyond the power of the naked eye.

(*v*) *Analysis of pattern elements.*—The formal analysis of such a complex system of patterns and subpatterns is of much interest. Half a dozen category-groups found to yield useful results, both singly and in combination, may be outlined.

(*a*) *Simple regional occurrence.*—It is sufficient to recognize three regions, head, trunk, tail. *A*, restricted to 1 region; *B*, to head; *BB*, to trunk; *BBB*, to tail; *AA*, no [*i.e.*, not as in *A*; and similarly throughout below]; *C*, on 3 regions; *CC*, on 2 regions only; *D*, on head and trunk; *DD*, on trunk and tail; [formally: *DDD*, on head and tail]. [This set used in combination with any or all of (*b*)-(*f*) below].

(*b*) *Simple surface occurrence.*—*A*, restricted to 1 surface; *B*, dorsal; *BB*, lateral [exceptionally: *C*, right; *CC*, left]; *BBB*, ventral; *AA*, no; *D*, occurring on 2 surfaces [*E*, *EE*, *EEE* for combinations of surfaces]; *DD*, on 3 surfaces.

(*c*) *Size, pure spatial disposition.*—*A*, at macroscopic (naked eye) level continuous; *AA*, no; *B*, continuous at microscopic (X10) level; *BB*, no. Then follow either *AA*, or *BB*, or both, with: *C*, marking single; *CC*, no; *D* in pair; *E* single marking paired; *EE* group (2 or more) paired; *DD*, in set of more than 2 (serial); *F* serial rectilinearly; *FF*, serial curvilinearly; *H*, in open curve; *HH* in closed curve. [If *C-HH* used with both *AA* and *BB*, reletter, at second time, from *I* to *LL*].

(*d*) *Sculpture-determined, in respect of surface involved.*—*A*, marking not determined by sculpture [*i.e.*, color elements not following local pattern of exoskeletal elevations and/or depressions]; *AA*, yes; *B*, surface-restricted [with *B's* of (*b*)]; *BB*, no; *C*, not sculpture-determined on both surfaces; *D*, determined on origin-surface only [origin surface—that on which most of the marking is located: if equally distributed, or if degree of sharing varies from occurrence to occurrence of marking, accept priority-sequence, dorsal, lateral, ventral]; *DD*, on other surface only; *CC*, on both surfaces. [This series combines naturally with (*b*), and (*e*)].

(*e*) *Sculpture-determining, in respect of degree of coincidence of marking and sculpture.*—*A*, marking and sculpture-unit exhibit coincidence; *B*, wholly coincident; *BB*, partly; *C*, marking coincides with part of sculpture-unit only; *CC*, coincides with whole of sculpture-unit and spills over; *AA*, no; *D*, marking the smaller item; *DD*, the larger.

(*f*) *One-many, and cognate, relations.*—Another general line of approach is as follows. Let an italic lower-case letter denote 'one' and a capital italic letter 'many.' Consider, first, marking surface relations; and let the initial letters of the words 'marking' and 'surface' designate these elements. Then we can have: *ms*, one-one (one marking [throughout, in this context—of a given

kind] on one surface); *mS*, one-many (one marking extending on to more than one surface); *Ms* many-one (many markings on one surface): [since the object of the analysis is (at the normal level of investigation) to classify specific types of markings, the fourth combination, *MS*, is not pragmatically significant]. Similarly, there can be recognized a set of marking-annulus relations: *ma*, *mA*, *Ma*, [*MA*]; while logically prior to this lies the broad dichotomy, not treates in this summary account, of segmental, non-segmental. There is empirical justification also for a suite of marking-sculpture relations: deriving letter symbols from 'marking,' as before, and 'engraving' (or 'embossing'), we get: *me* (one marking on one sculpture-unit), *mE*, *Me*, [*ME*]. Further formulations, not without actual exemplifications, include those formed by the substitution, in the three systems above, for 'one or many markings of a given kind' of 'one or many kinds of markings.'

(*vi*) *The cross-bars.*—The cross-bars, most highly developed (except 2nd, which is largely confined to dorsal surface) on lateral surface, involve up to 2 annuli (band on nape narrowest, most sharply delimited), the anterior being in general larger than the posterior. With 2 on head, 4 on trunk, 15 on tail they occur in these 3 primary regions at the rate of 1 per 6.50, 9.30, 9.94 mm, respectively, of anteroposterior extension. The increase caudad of the ratio, number of bars/length from tip of snout is a simple one. With X = length to posterior extremity of region (13, 50.2, 139.7 mm), and Y = number of bars to that extremity (2, 6, 15), we find $Y = 0.1022\ X + 0.76$ (giving $Y^1 = 2.1, 5.9, 16.0$); $t = 64.74^{**}$. The Y-intercept is small; and if the assumption is made that the true relation is one of direct proportionality ($Y = mX$), the coördinates (0, 0) being taken as a fourth point, the equation for the best straight line becomes $Y = 0.1053\ X + 0.40$ ($Y^1 = 0.4, 1.8, 5.7, 15.1$); $t = 28.59^{**}$. The increase caudad of the mean interval between bars is conceivably associated with greater relative growth in the more posterior part of the fish (see data above on Mr Green's sample; Table II). If such is the case, there may be postulated a stage (perhaps coincident with the full establishment of this pattern) at which the bars are equidistant throughout the whole length. On the evidence afforded by Mr Green's material and Miss Mather's specimen the pattern appears at *Lt* 100-140. Waite & Hale (1921: 301), who describe the coloration of 'an adult male' and 'a female' unfortunately note only the length of their largest example (164 mm). Earlier McCulloch & Waite (1918: 40) gave an account, based on two males and two females, 125-164 long, in the course of which it is noted 'the markings vary in intensity in different specimens, but are similarly arranged in all': the color pattern of 'an adult male' is then described. Neither the 1918 nor the 1921 account makes mention of the broad cross-bars here discussed.

If the heuristic assumption is made of a first-degree relationship, in each of three main morphological regions, between numbers of bars (caudad: 2, 4, 9) and number of annuli (x 18, 44), the predicted number for the head is 7-8 (7.6), which is in general agreement with the value suggested by some studies of development in pipefishes.

SYNGNATHUS TUCKERI Scott, 1942

Syngnathus tuckeri Scott, 1942, *Rec. Queen Vict. Mus.*, I, 1: 17, pl. V. Type locality: Bridport [Dorset], Tasmania; netted in shallow water.

Syngnathus tuckeri Scott. Munro, 1958, Handbk Aust. Fish.: 82, fig. 568 [instalment No. 20 in *Fisheries Newsletter*, XVII, 2, February 1958: 18, fig. 568].

Mitotichthys tuckeri (Scott). Whitley, 1958, *Rec. Aust. Mus.*, XXII, 1: 75. Scott, 1960, *Pap. Proc. Roy. Soc. Tasm.*, 94: 87.

General remarks.—Some comments on the generic status of this fish have been made earlier in these Observations (1960: 87): I here follow the conservative action of Munro (1958) in continuing to refer it to *Syngnathus* Linné; though not without some feeling the institution of *Mitotichthys* Whitley, 1948 to receive it may turn out to be justifiable.

I know of only 5 individuals: (*a*) the holotype, ♂, *Ls* 121.3, *Lt* 126.6, Bridport, Dorset, 1941 (G. V. Tucker); (*b*) ♀, *Ls* 91.2, *Lt* 95.6, Piper River Heads, Dorset, 1956 (Holyman); (*c*) unsexed, *Lt* 37, Piper River Heads, October 1957 (M. C. Burns); (*d*) ♂, *Ls* 126.9, *Lt* 132.4, Piper River Heads, November 1957 (J. Allchin); (*e*) ♂ *Ls* 132.6, *Lt* 137.9, locality unknown (Queen Victoria Museum, Launceston). Some data on (*b*), (*d*) have been published previously (1960): the only items, apart from *Lt*, available from Mr Burns' specimen, (*c*), are annuli 22 + 43, subdorsal annuli 10 + 2, dorsal 32. Of the 3 known males, the holotype carried eggs *in situ* (1942: 18; pl. V, fig. 3) (*d*) yielded a fusiform egg-mass that worked clear of the pouch after preservation of the fish (1960: 83); while (*e*) carries pouch young.

Fin counts, dimensions of (*e*).—The principal dimensions and meristic characters of (*e*) are here recorded for comparison with published information on other examples. Annuli 20 + 40. Subdorsal annuli 9.6 + 2.0. Brood annuli caudal 1.0-12.8. Dorsal 36. Pectoral 13. Anal 5. Head 17.8, eye 2.3 (orbit 2.5); interorbital 1.2; snout 9.2; length to origin, termination, of dorsal fin 40.0, 57.7; vertical height of dorsal, longest ray 5.4, 5.8; length of pectoral, pectoral base 4.5, 2.6; length to vent 52.4; *Ls* 132.6, *Lt* 137.9; depth (in parentheses, width) at opercular margin, middle of trunk, vent, middle of tail 4.6 (3.0), 4.0 (3.5), 4.0 (3.4), 1.9 (1.9).

Extensions of conspectus values.—Examination of specimens (*e*), (*c*) leads to the following new entries in the conspectus (see paragraph with same heading as this in treatment of *Syngnathus curtirostris*, above): brood annuli, caudal 1.0-12.8 (previously 1-12); dorsal rays 32-36 (33-35); eye in snout 3.1-3.7 (3.1-3.3); trunk in tail 2.1-2.5 (2.1-2.3); total length 138 (previous maximum 132).

Dimensions and proportions.—Table III sets out, for 8 basic dimensions, the same data as those given in Table I for *S. curtirostris*. In spite of the size of the sample, still smaller in this than in the preceding species, the correlation of X (body region) and Y (*Lt*) continues in general to be high, failing to reach a significance of P 0.05 in 2 dimensions only (eye, postorbital head), and in

3 dimensions having a significance better than P 0.01. The absolute magnitudes as calculated from the regression equations are again seen in most cases to approximate closely the raw data (showing for the two large divisions, preanal and post anal length a maximum absolute divergence of 0.4 mm, or 0.5%, a maximum percentage divergence of 0.6%, and a mean divergence of 0.21 mm. or 0.32%). This measure of reliability is the more striking in that these specimens, unlike the examples of *S. curtirostris* discussed above, were not collected as one sample; though, indeed, except in the case of (*e*), the source of which is not recorded, they come from the same locality.

In this species, as in *S. curtirostris*, the relative length of tail increases with increase in overall length, the *TLt* values rising consistently across the table from left to right; concomitantly of course the total preanal length suffers corresponding relative decrease: with the length-range (44.3 mm) of the present sample, the variation (4%-6%) is small in terms of the wide tolerances found in some specific diagnoses. Unbroken sequences of entries characterize also trunk and eye (in table, rounding makes last 2 entries for eye identical); while for snout and head there are good indications of a trend, with increasing *Lt*, towards relative increase, decrease, respectively, of length of relevant region. As in both Table I and Table II, the correlation between proportion of *Lt* represented by body-region and magnitude of *t* is striking (Spearman's rank-correlation for the 2 sets here is 0.929).

TABLE III

Syngnathus tuckeri Scott, 1942. Three specimens, (*b*), (*c*), (*d*) from Piper River Heads, Dorset, Tasmania, one (*e*) of unknown locality. Anteroposterior lengths of 8 specified regions—absolute (mm), first, as measured, secondly, as estimated from regression equation (recorded, with indication of significance) of relevant region (*Y*) on total length, *Lt* (*X*); relative, as thousandths of total length, *TLt*: also correlation of *X* and *Y*

Region (*Y*)		Specimen *Lt* (mm) (*X*)				Correlation of *X* and *Y*		Regression of region (*Y*) on *Lt* (*X*)	
		(*b*)	(*c*)	(*d*)	(*e*)	*r*	*z*	Equation	*t*
		95.6	126.6	132.4	137.9				
Snout	Measured	6.2	7.5	7.7	8.5	0.965*	2.003	$Y = 0.04880\ X - 1.53$	5.49*
	Estimated	6.1	7.6	7.2	8.2				
	TLt	65	59	58	62				
Eye	Measured	2.0	2.4	2.3	2.3	0.874	1.351	$Y = 0.08012\ X + 1.26$	1.89
	Estimated	2.0	2.3	2.3	2.4				
	TLt	21	19	17	17				
Postorbital head	Measured	4.9	5.8	6.1	7.0	0.916	1.562	$Y = 0.04216\ X + 0.76$	3.30
	Estimated	4.8	6.1	6.3	6.6				
	TLt	51	46	46	51				
Head	Measured	13.1	15.7	16.1	17.8	0.960*	1.943	$Y = 0.09898\ X + 3.49$	5.11*
	Estimated	13.0	16.0	16.6	17.1				
	TLt	137	124	122	129				
Trunk	Measured	25.5	33.6	34.9	34.6	0.981*	2.314	$Y = 0.2326\ X + 3.51$	8.64*
	Estimated	25.7	33.0	34.3	35.6				
	TLt	267	265	264	251				
Preanal region	Measured	38.6	49.3	51.0	52.4	0.999**	3.827	$Y = 0.3315\ X + 7.00$	32.12**
	Estimated	38.7	49.0	50.9	52.7				
	TLt	404	389	385	380				
Tail	Measured	57.0	77.3	81.4	85.5	1.000**	4.511	$Y = 0.6685\ X - 7.04$	64.78**
	Estimated	56.9	77.6	81.5	85.1				
	TLt	596	611	615	620				
Dorsal base	Measured	12.3	16.0	17.3	17.7	0.993**	2.831	$Y = 0.1294\ X - 0.11$	15.30**
	Estimated	12.3	16.3	17.0	17.7				
	TLt	130	126	131	128				

Percentage length increments.—A table of percentage length increases for this species comparable with Table II for *S. curtirostris* has been made out; but in view of the generally small *t* values encountered it has not been thought worth while to publish it. With only 1 degree of freedom available, as in the present data, the approximation to linearity has of course to be extremely close and *t* values very high—divergences from an ideal model of magnitudes biologically expectable that would yield statistically significant evidence of consistency in a larger series failing to do so when encountered, as here, among only 3 entries. For the two larger regions, however, significant coefficients do characterize the regressions of percentage increments, in preanal length and in tail length, of individuals (*c*), (*d*), (*e*), on (*b*), (*Y*), on the corresponding increments in *Lt* (*X*). For the preanal region the equation is $Y = 0.6398\ X + 7.50$ ($t = 45.59^{*}$); for postanal region $Y = 1.1437X - 0.75$ ($t = 31.07^{*}$): a test of the significance of the difference between these two regression coefficients gives $t = 9.93^{**}$.

The average percentage increases in length relative to percentage increase of *Lt*—arithmetic mean cited definitively (with geometric mean in parentheses)—for the 8 body regions studied, listed in the same order as in Table II for *S. curtirostris* are as follows: snout 0.705 (0.700), eye 0.499 (0.434), postorbital head 0.725 (0.705), head 0.674 (0.667), trunk 0.916 (0.913), preanal region 0.834 (0.834), tail 1.112 (1.112), dorsal base 0.994 (0.992). Though for each region only 4 specimens are involved, making available 3 percentages, the general stability that characterizes the mean, taken in conjunction with the marked general parallelism of the present results with those already found for *S. curtirostris*, would suggest the figure just given might well provide a probable picture of the chief features of the actual situation. In both species, we find that in the head the postorbital element has the highest increase relative to *Lt* increase, followed in turn by the snout and the eye; however, in *S. tuckeri*, entry for snout exceeds (in *S. curtirostris* is 0.77 of) entry for total head, thus compensating for the much lower datum in *S. tuckeri* for postorbital head. In both species, value for trunk exceeds that for head (difference more pronounced in *S. tuckeri*). In both species, relative percentage increase of postanal region exceeds that of preanal (with very similar ratios: in *S. tuckeri* postanal value is 1.26 preanal, in *S. curtirostris* 1.19). In both species, dorsal base value exceeds head value and trunk value (but in *S. tuckeri* dorsal base entry is less than tail, greater than postorbital, entry; while the inverse obtains in *S. curtirostris*).

Pouch young.—The specimen carries an apparently full complement of pouch young, with which it is hoped to deal in a subsequent contribution.

Family GERRIDAE

Of the 3 genera occurring in Australia, *Gerreomorpha* Alleyne & Macleay, 1877, with 1 species, is restricted to Queensland; *Gerres* Quoy & Gaimard, 1824 is met with chiefly in our northern waters [of the 14 species recognized in the Check List Queensland has 12, Northern Territory 4 (all extending also to Queensland, 1 shared with New South Wales and South Australia), New South Wales 3 (one endemic), Western Australia 3 (one endemic); while 5 range extralimitally]: *Parequula* Steindachner, 1879, with 1 species, has hitherto been known only from the two southern States of Victoria and South Australia—this last entry, *Parequula melbournensis* (Castelnau), 1872, is now reported for the first time from Tasmania.

Schultz (1953: 556) recognizes the Gerridae and the Leiognathidae as a single family, the latter name prevailing.

Genus **PEREQUULA** Steindachner, 1879

PEREQUULA MELBOURNENSIS (Castelnau), 1872

Gerres melbournensis Castelnau, 1872, *Proc. Zool. Acclim. Soc. Vict.*, 1: 158. Type locality: Melbourne, Victoria.

Parequula bicornis Steindachner, 1879, *Denks. Akad. Wiss.* Wien, xli, 1: 8. Type localities: Hobson Bay (Müller) and Murray River.

Chthamalopteryx melbournensis (Castelnau). Ogilby, 1887, *Proc. Zool. Soc.*: 616; unnumbered fig.

Tasmanian record.—A specimen, *Ls* 158.5, *Lt* 209.5, length to end of middle caudal rays 184.8, caught at Kelso, Devon, by Mr Bruce Porter on 7th July 1963 (Queen Victoria Museum Reg. No. 1963.5.4) adds this species to the Tasmanian list.

Meristic characters.—D. IX, 17. A. III, 17. P. 15 (right), 16 (left). V. I, 5. C. 17 (i.e., 8 + 1 + 8) + 5/5. L. lat. 34.

Proportions, TLs.—Measurements were made to to the nearest tenth of a millimetre; where its presence is necessary to allow of recovery of the raw data to this degree of accuracy, one decimal digit is recorded in the entries of thousandths-of-standard-length below. Lengths to dorsal, anal, pectoral, pelvic origins 303, 508, 296.5, 284. Bases of spinous dorsal, soft dorsal, anal 303, 566.6, 378. Snout, eye, interorbital, head, 82, 92, 99.7, 284. Length to vent 486.4. Depth at front of eye, back of eye, dorsal origin, vent 202, 287, 435, 473; caudal peduncle 90. Lengths of 1st-8th dorsal spines (9th imperfect) 58.7, 77, 96.5, 107, 113.6, 107, 106.6, 102. Lengths of 3rd, 8th, 10th, 14th, 15th, 16th, 17th dorsal rays 148, 176.7, 171.6, 131, 120.5, 99, 87. Lengths of anal spines 44.8, 66, 84. Lengths of 2nd, 3rd, 9th, 15th, 16th, 17th anal rays 114, 109, 107, 92, 81, 77.6. (Dimensions of dorsal, anal spines, rays represent full lengths, measured from base, inside sheath). Length of pelvic spine; 1st-5th rays 110.4; 150, 152.7, 143, 122, 101. Longest (4th) pectoral ray 246.

General remarks.—Comparison of the characters of Mr Porter's specimen with those given in the original description (1872 *a*) reveals some variations: items in parentheses in this paragraph relate to the Tasmanian fish. Height in length without caudal two and a half times (2.1). Eye in head, mouth not extended, two and two-thirds (3.1). 'The profile is very convex over the eye and the snout' (somewhat convex). Head, with mouth shut, four times (4.7) in total length. Of the

dorsal spines 'the first one is shorter than the following, which are about equal, the posterior ones being somewhat longer than the others' (increase to 5th, then decrease to 8th, probably to 9th, imperfect): longest spines equal to diameter of eye (1.23 eye). Dorsal rays 16 (17; recorded range 16-17): 'the first are about the same length as the last spines, but they become rather longer as they go backwards' (1st, 2nd imperfect; 3rd is 1.5 8th spine: rays increase to 8th, then decrease, the last a trifle more than twice in 8th). 'Caudal of eighteen long rays and of several shorter ones on each side' (8 + 1 + 8 + 5/5). Pectoral 15 (15, 16) 3rd (4th) longest. Eye twice (2.7) in caudal at its sides. Operculum, preoperculum, preorbital entire (angle, and one-fourth, or more, of posterior border of preoperculum denticulate).

The Tasmanian fish differs in some points from the standard figure (Ogilby's) reproduced in Australian catalogues. In the specimen the (rather less convex) sweep of the dorsal profile from tip of upper jaw continues to about level of middle, instead of about anterior one-fifth of eye, and beyond this the steeply rising curve runs unbroken to dorsal origin, the projection above eye that in the illustration forms a noticeable feature of the outline being much less developed and not reaching the profile: superior border of eye is further below profile than in figure: with mouth protracted as in figure, maxilla, which, as depicted and described, extends to anterior border of eye, fails to reach level of posterior nostril by a distance equal to eye-nostril interval, and even with mouth closed, reaches only to level of nostril: longest dorsal ray subequal to combined eye and snout (in figure, subequal to eye): outer caudal rays more produced, more than twice (figure, about one and a half times) middle rays. It agrees tolerably well with Ogilby's description (1887: 616), based on 2 examples 4½ and 5 1/6 inches long. Points worthy of comment (apart from those already dealt with in the above comparison with his figure) are: preorbital 6/7 of eye-diameter (in our specimen 1.1); dorsal spines gradually increase in height to last two or three, which are equal (increase to 5th, then decrease to 8th, probably to 9th, imperfect); ventral does not quite extend to vent (very briefly beyond).

Some amplifications of the original account may be noted. Gillrakers on lower limb anterior arch 7, subcylindrical, distally somewhat curved cephalad, the extremity usually flattened and sometimes slightly expanded; their height subequal to their interspaces: on upper limb 3-4, smaller, the uppermost minute. This species is noted (Scott, 1962: 201) as having the body and head covered with large cycloid scales. In our specimen scales are present on the side of the head, much like those illustrated. However, the region delimited on either side by a line running from preorbital border, at a little below level of nostrils, to nostrils, thence back along superior border of orbit to level of hindmost extension of orbit, and thence to middorsal line (meeting this at end of prominent middorsal ridge which extends cephalad from dorsal fin to this point, in advance of which the compressed body suddenly gives way to the much-depressed upper surface of the head) is in our specimen wholly naked: this is in agreement with Ogilby, 'interorbital space, snout, and preorbital absolutely scaleless'—as noted in his account, scales of cheek extend on to mandible. Much of this region bears numerous pores of varying size: a particularly marked concentration of pores, with upwards of 50 in a lunule about 10 mm long and 2-3 in greatest width, occurs adjoining the hinder half of the superior border of the orbit, the openings being here so closely set as to present a honeycomb appearance. Numerous pores are found on the somewhat raised annulus of the orbit, including a continuous series of about 50, very closely set, extending from the lunule just noticed downwards and forwards, covering in all about half the ocular circumference. Other notable pore-groups include a sigmoid band from near middorsal line to near upper end of operculum; a series, in 1-4 rows, along lower two-thirds of posterior, and whole of free lower, borders of preoperculum; a small collection below, and in advance of, the nostrils. On first examination the premaxillary groove gave the impression of being naked: however, probing yielded one tolerably large, somewhat incomplete scale. Two small, but stout subconical glassy spines, about 2 mm long, the interval between their bases equal to one-third of eye diameter, project from the anterior margin of the preorbital over the groove, their tips reaching to within a distance subequal to their length from the anterior surface of the upper lip: left spine (probably normally) simple, right bifid Villiform teeth very slender, mostly much recurved; the dentigerous area several times wider anteriorly than laterally. Small adipose eyelid, best developed round inferior and lower half of posterior borders of eye. Anterior nostril small, less than its own longer (horizontal) diameter from the posterior, which is a little more than its own major (subvertical) axis from the orbit.

In this specimen part of the pectoral girdle is visible at the surface (possibly through the loss of deciduous scales, as the relevant region is depicted in the standard figure as normally scaled): by pulling on the pectoral fin it is possible to lift somewhat the whole structure from about level of mid-eye to level of bottom of pectoral base, revealing a shallow cleft, the floor of which is largely covered by formed and partly pigmented scales. As a purely individual variation, both fins have most of the pectoral rays more or less sinuous, this feature being most marked in the upper, stronger rays (which are simple, undivided rods throughout the whole, or almost the whole, of their length).

This species possesses no accessory pelvic appendage such as that found in *Gerres*. The two preorbital spines noted above were not mentioned in Castelnau's original account, but in a single-sentence comment in a supplement (1873 *a*: 37) he remarks, 'In the male we find the preorbital forms on each side, a spine in front'. Ogilby includes the character 'Preorbitals with a blunt bony protuberance in front' in the diagnosis of his *Chthamalopteryx*, based on this species.

Family NEOODACIDAE

Four species are already ascribed to Tasmania: (*a*) *Olisthops* Richardson, 1850, (1) *O. cyanomelas* Richardson, 1850; (*b*) *Haletta* Whitley, 1947, (2)

H. semifasciata (Cuvier & Valenciennes), 1840; (*c*) *Neoodax* Castelnau, 1875, (3) *N. balteatus* (Cuvier & Valenciennes), 1838, (4) *H. attenuatus* (Ogilby), 1897. The type locality of (2), given as 'Mers des Indes' (Peron) and that of (3), not recorded (Péron) are identified in the Check List (McCulloch, 1929) as Tasmania: this State is also the source of the unique holytype of (4).

To this short list may now be added (5) *N. radiatus* (Quoy & Gaimard), 1835, a specimen of which from Low Head, Dorset, is noted below.

Other names that have at various times appeared in local catalogues include (*i*) *Odax richardsoni* Günther, 1862; (*ii*) *Odax algensis* Richardson, 1840 (type locality: Port Arthur, Pembroke, Tasmania); (*iii*) *Olistherops brownii* Johnston, 1884 (type locality: Table Cape, Wellington, Tasmania); (*iv*) *Odax beddomei* Johnston, 1885 (type locality: Derwent River, Monmouth/Buckingham, Tasmania). Of these (*i*), (*ii*), (*iii*) are synonyms of (2), (3), (1), respectively; while the examination by McCulloch of a sketch found among R. M. Johnston's memoranda—later published by Whitley (1929, pl. IV, fig. 6)—led to his recognition of the fact that Johnston's fish was a species of *Siphonognathus* Richardson, 1858 (Family Siphonognathidae: differs trenchantly from Neoodacidae in lacking ventral fins).

Key to Neoodacidae Recorded from Tasmania

1. Check without scales. Deep notch between spinous and soft dorsals; height of last spine $< \frac{1}{2}$ (usually $\leq \frac{1}{3}$) height of longest ray. Caudal lunate, its outer rays somewhat (female) considerably (male) produced .... *Olisthops cyanomelas*
   Cheek with scales. No deep notch betwen spinous and soft dorsals; height of last spine $> \frac{1}{2}$ usually $= \frac{1}{2}$) height of longest ray. Caudal rounded or pointed (unknown in *N attenuatus*) 2

2. Lateral line $>$ 50 (53-63) .... *Haletta semifasciata*
   Lateral line $<$ 50 (39-45) 3

3. First dorsal spine produced (to about 2 length of second spine). Outer ray or rays of ventral produced (fin $=$ head). A black longitudinal bar along base of dorsal, covering about a dozen of the posterior spines and anterior rays: above this 4-5 thin light subparallel lines. Caudal pointed .... *Neoodax radiatus*
   First dorsal spine not produced ($=$ second spine). Outer ray or rays of ventral not produced (fin $= \frac{1}{2}$ head). No such bar or lines on dorsal. Caudal rounded in *N. balteatus* (unknown in *N attenuatus*) 4

4. Dorsal spines and rays combined $<$ 32 (XVI-XVII/12-13). Anal spines and rays combined $<$ 17 (III/12). Sc. tr. $>$ 14 (4/13). Depth of body $<$ 7 (5-6) in total length. *Neoodax balteatus*
   Dorsal spines and rays combined $>$ 32 (XX/15). Anal spines and rays combined $>$ 17 (19). Sc. tr. $<$ 14 (4/6). Depth of body $>$ 7 (8-9) in total length .... *Neoodax attenuatus*

Genus NEOODAX Castelnau, 1875

NEOODAX RADIATUS (Quoy & Gaimard), 1835

Malacanthus radiatus Quoy & Gaimard, 1835, Voy. *Astrolabe*, Zool., III: 717, pl. XIX, fig. 2. Type locality: King George's Sound, Western Australia.

Neoodax radiatus (Quoy & Gaimard). McCulloch, 1929, *Mem. Aust. Mus.*, V. 1: 324 (synonymy). Scott, 1962, The Marine and Fresh Water Fishes of S. Aust.: 282, unnumbered fig. on p. 282.

Tasmanian record.—Known hitherto only from Western Australia and South Australia—in which latter State it is 'not very common' (Scott, 1962)—this species may now be added to the Tasmanian list, an example, *Ls* 152.0, *Lt* 189.5, having been caught (on hook; meat bait) in the Tamar estuary, off Lagoon Bay, Low Head, Dorset, in green kelp, at 3-4 fathoms, by Mr R. Askeland during the latter part of January 1962.

Variation in dorsal.—The dorsal formula is usually given as XVII/12-13: in Mr Askeland's fish the count is XX/12 (last cleft to base). In the figure regularly reproduced in Australian works—*e.g.*, Scott (1962, unnumbered on p. 162), Whitley (1962, unnumbered, on p. 219)—which is Richardson's (1848, pl. IX) illustration of his synonymic *Odax lineatus* (type locality: King George's Sound, Western Australia)—the fin is depicted with a pronounced bight in its anterior one-third, the height of the spines dropping sharply from 1st (much produced) to 3rd, remaining virtually constant to 6th or 7th, rising to 9th, which is subequal to 10th, and then through the remaining 2 spines and the whole series of rays (except perhaps the last, which may be a trifle longer than the penultimate) decreasing evenly caudad, the penultimate ray being contained about one and a half times in 10th spine. In the local specimen the fin profile, after the initial fall from 1st to 2nd spine, is quite without local excavation, and makes a rounded sweep back to about middle of soft portion (5th ray about twice in 10th spine, which is a trifle longer than 3rd), behind which ray-length continually increases, the penultimate ray being about 0.9 of 3rd spine.

It is difficult to assess the significance of these variations. An examination of literature at hand shows for species of this genus (*s.l.*, including *Haletta* Whitley, 1947) a modal reporting of a single entry for spine-number, with an occasional variation of up to one spine. Speaking of the commonest mainland species of rock whiting, *Haletta semifasciata* (Cuvier & Valenciennes), Castelnau (1872 *a*: 153) observed, 'Authors generally attribute a larger number of rays to the dorsal (thirty-two) than I have mentioned ['thirty rays, the latter eleven branched, the others being very soft, it is often very difficult to distinguish one from the other'], but I have seen many thousands of this fish, and I have always found the same number.' It is possible the excess in the Tasmanian fish of 3 spines over the total usually reported in conjunction with the absence of the characteristic dip in the early portion of the fin may be indicative

of specific or subspecific distinction. With only a single example available, it seems expedient to treat these variations, at least for the present, as merely individual. In any case it would appear to be desirable to record the chief features of the specimen.

Meristic and other metrical characters.—D. XX/12 (last split to base). A. III/10 (last split to base). V. I/4. P. 13 (usually reported, 12). L. lat. *ca* 46. Proportions are shown, as *TLt*, in Table IV. (In several entries one decimal figure is recorded in the table: this makes possible the recovery of all absolute dimensions correct to the degree of accuracy of measurement, namely, one-tenth of a millimetre.)

TABLE IV

Neoodax radiatus (Quoy & Gaimard), 1835. Proportions, as thousandths of total length (*TLt*), of a specimen, *Ls* 152.0, *Lt* 189.5, caught in the Tamar estuary, off Lagoon Bay, Low Head, Dorset, Tasmania, January 1962

Dimension	*TLt*
Length to dorsal origin, termination	276, 825.7
Length to anal origin, termination	628, 789.5
Length to vent	622
Length to pectoral, ventral, origin	263, 322
Head, with, without soft opercular lobe	283, 260
Snout	106
Eye, interorbital	47, 55
Depth at front of eye, back of eye, end of head (with opercular lobe), vent	95.4, 115, 168, 164.5
Maximum depth	172.4
Caudal peduncle	92
Dorsal spines: 1st, 2nd, 3rd, 4th, 5th, 8th, 10th, 20th	189.5, 115, 102, 106, 105, 112.5, 112,7, 115
Dorsal rays: 1st, 6th, 8th, 11th, 12th	112, 66, 60, 85.5, 98
Anal spines: 1st, 2nd, 3rd	52.6, 85.5, 102
Anal rays: 1st, 5th, 9th, 10th	106, 77.6, 72.4, 69
Ventral: spine, 1st ray, 4th ray	145, 283, 68.6
Pectoral: longest (6th ray)	112

General features.—Greatly produced ventral reaches to vent; distal half of 1st ray filamentous. Maxilla fails to reach level of eye by half eye-diameter. Scales on dorsum of head terminate in two large median scales, the anterior borders of which lie midway between levels of nostril and front of eye: on cheek continued forward virtually to rictus, rather irregularly disposed, in 2-3 rows between eye and preopercular border: between, and partly obscuring, bases of ventrals, two pairs of specialized scales; the longer pair together forming a lanceolate, largely free flap, subequal to orbit, overlapped in their proximal half by the anterior pair, each of which is rather bluntly lobate, the right superimposed upon the left mesially: scales on caudal base extend one-third of distance from hypural joint to tips of longest (middle) rays. Pectoral base about 2½ in longest ray (in Richardson's figure <2), subequal to eye. Ventrals inserted midway between tip of lower jaw and 1st anal ray. After running back subparallel to dorsal profile of body for a distance equal to half head, the lateral line descends rapidly, in the course of 2-3 scales, to begin its longest, almost straight segment about below 9th dorsal spine: at least one (long) tubule extends beyond hypural joint.

Mr Askeland noted the general color as green; some conspicuous green spots; no red longitudinal stripe noted; dorsal (which, on preservation, exhibits the characteristic lineal pattern) 'rainbow.'

Family APOGONIDAE

The following species have at one time or another appeared on the Tasmanian list: (*a*) *Dinolestes* Klunzinger, 1872; (1) *D. lewini* (Griffith), 1834; (*b*) *Vincentia* Castelnau, 1872; (2) *V. guntheri* Castelnau, 1872; (3) *V. novaehollandiae* (Valenciennes) 1832; (4) *V. lemprieri* (Johnston, 1883): (*c*) *Lovamia* Whitley, 1930; (5) *L. fasciata* (Shaw), 1790: (*d*) *Siphamia* Weber, 1909; (6) *S. cephalotes* (Castelau), 1875 [the last species is not noticed in the Check List (McCulloch, 1929)].

In his first list Johnston (1883) gives (1) (as *Lanioperca mordax* Günther, 1872 (family Sphyraenidae), of which Tasmania is the type locality, the British Museum type specimen having been forwarded by Allport, the inclusion in whose MS list of this species is noted by Johnston); (2) (with the notation: 'Rare. Considered by Mr Macleay [*i.e.*, Macleay (1881: 345)] that it may be identical with Val., *A. Novae Hollandiæ*'): with (4) described in the Addenda (p. 142). His second list (1891) is similar, but with (4) now incorporated as a normal entry. In both lists (2) and (4) are referred to *Apogon* Lacépède, 1802.

Lord (1923) admits (1), (3) (with which (2) is presumably now synonymized), (4), (5), the three small forms remaining in *Apogon*. In their preliminary enumeration of species (pp. 5-15) Lord & Scott maintain this position [in the main text *Ostorhinchus conwaii* (Richardson), 1840 (family Opleganthidae), entered as *Ostorhinchus conwayi*, intrudes, by an oversight, between a brief mention of (3), (4), (5) and an account of (1)].

The Check List (McCulloch, 1929) credits this State with (1), (3) (of which (2) is formally treated as a probable synonym), (4); of which (3), (4) are still referred to *Apogon*.

The Handbook (Munro, 1960) admits as Tasmanian (1), (3) (with (2) and (4) as synonyms), (5), (6) (this last with the notation: 'New records for W.A. and Tas. based on examples from Lady Barron I. [Bass Strait], Israelite Bay and Shark Bay'). Of these 4 species, (1), (3), (6) are recorded from Western Australia, South Australia, Victoria, Tasmania, New South Wales; while (5) is reported from Tasmania, New South Wales, Queensland, Northern Territory.

Evidence discussed below suggests the reinstatement on our local list of Johnston's species, (4) (type locality: Dunkley's Point, Sandy Bay [Buckingham]), thus giving this State 5 species, a key to which is subjoined. [By some recent authors, *e.g.*, Scott (1962: 184), (1) is treated as constituting the family Dinolestidae.]

KEY TO APOGONIDAE RECORDED FROM TASMANIA

1 Total length > 300 (≧ 500). Second dorsal: without spines; rays > 13 (≧ 18). Anal rays > 15 (≧ 25). L. lat. >40 (≧ 65). Pelvic origin caudad of pectoral origin. *Dinolestes lewini*

Total length < 300 (≦ 120). Second dorsal: with 1 spine; rays < 13 (≦ 10). Anal rays < 15 (≦ 10). L. lat. < 40 (≦ 28). Pelvic origin cephalad of pectoral origin 2

2 Subcutaneous gland (silver, black-edged) forming a tube along, and in front of, anal base. First dorsal: 6 spines; separated from second by < ½ its own base. Maxillary to below middle of eye . . . . . *Siphamia cephalotes*

No such gland. First dorsal: 7 spines; united with second, or separated from it by < ½ (⅓-⅔) its own base. Maxillary to beyond middle of eye 3

3 With dark horizontal stripes on body (1st along dorsal profile, sometimes indistinct; 2nd from upper edge of eye to upper caudal peduncle; 3rd, widest, from snout, through middle of eye, across middle of caudal peduncle: in older examples 2 additional stripes, one on each side of lateral line, may appear). Dusky sub-basal streaks through second dorsal and anal. Anal base ≧ eye + snout. First dorsal: longest spine < eye + snout; base ≦ base of second dorsal . . . . . *Lovamia fasciata*

No such dark stripes on body. No such streaks through second dorsal and anal. Anal base < eye + snout. First dorsal: longest spine spine > eye + snout; base > base of second dorsal 4

4 Dorsals united. Teeth in jaws 'fine villiform.' Longest dorsal spine ≐ distance from tip of snout to hinder angle of preopercular ridge. Interorbital < 2 (1.0-1.1) eye . . . . . *Vincentia novaehollandiae*

Dorsals separate. Teeth in jaws minute, subconical. Longest dorsal spine < (about 4/5) distance from tip of snout to hinder angle of preopercular ridge. Interorbital ≧ 2 (2.0-2-4) eye . . . . . *Vincentia lemprieri*

Genus VINCENTIA Castelnau, 1872

VINCENTIA LEMPRIERI (Johnston), 1883

(Fig. 1)

Apogon lemprieri Johnston, 1883, *Pap. Proc. Roy. Soc. Tasm.*, 1882: 142. Type locality: Dunkley's Point, Sandy Bay [Buckingham], Tasmania.

Apogon lemprieri Johnston. Lord & Scott, 1924, Synopsis Vert. Anim. Tasm.: 10, 55. McCulloch, 1929, *Mem. Aust. Mus.*, V, ii: 172.

Vincentia novaehollandiæ (Valenciennes). Munro, 1960, Handbk Aust. Fish.: 144, fig. 901 [in *Fisheries Newsletter*, XIX, 10, Oct. 1960: 20, fig. 901], *partim.*

General remarks.—Johnston's species, based on a unique holotype, was described in the Addenda to his first catalogue: though it has survived on a number of succeeding lists (to become at last reduced in the Handbook to a synonym—together with *Apogon conspersus* Klunzinger, 1879, *Vincentia waterhousii* Castelnau, 1872, *Apogon guntheri* Castelnau, 1872, and *Mionorus ramsayi* Fowler, 1908—of *Vincentia novaehollandiae* (Valenciennes), 1832), it does not appear to have been recognized since its publication. A redescription and figure, based on 2 specimens that seem to be pretty clearly referable to it, are here offered.

Material.—Two specimens, (*a*), *Ls* 68.0, *Lt* 86.9, (*b*), *Ls* 73.0, *Lt* 91.1, from *Akaroa*, near St. Helens, George Bay, Cornwall, Tasmania: netted (Mr C. Burrows).

Description.—Where 2 comparable items (numerical or descriptive) occur in this account, the first entry relates to the smaller individual, (*a*).

D. VII, I, 9. A. II, 9. V. I, 5. P. II, 13. C. main rays 20; total 26, 24. L. lat. 27 + a terminal multiperforate scale on caudal base. L. tr. 2/1/9, 2/1/10.

Compressed; maximum thickness, occurring at posterior border of preoperculum, 4.9, 5.2, in *Ls*; thickness at level of vent 7.6, 7.7, at middle of length of caudal peduncle 16.6, 17.8, in *Ls*. Deep, maximum depth, occurring at level of first dorsal origin, 2.5, 2.6 in *Ls*, slightly exceeding length of head. General form more or less ovoid. In advance of eye, which in (*a*) barely reaches, in (*b*) cuts, dorsal profile of head, the upper profile is briefly in turn convex, concave, convex; between hinder part of eye and first dorsal origin profile shows in (*a*) an almost straight segment, followed (behind level of upper angle of preoperculum) by a segment, a little longer than an eye-diameter, the anterior moiety of which is shallowly concave, the posterior slightly convex; in (*b*) a short rather pronounced concavity, followed by a less well marked concavity, a short almost straight segment, and, at a noticeably lesser slope, a gently convex segment whose length is subequal to an eye-diameter. First dorsal base slightly concave, sloping slowly back and down: second dorsal base convex, the chord of the profile at an angle of about 35° to mediolateral axis. Upper part of caudal peduncle slightly concave, straight. In the ventral profile the most noticeable feature is the abrupt change in direction from the more or less even convex sweep from snout to end of anal base (this region rather more convex, near middle of its length, in (*a*) than in (*b*)) to the almost straight segment contributed by the caudal peduncle.

Head 2.6, 2.7 in *Ls;* 1.6, 1.8 times trunk. Eye 2.8, 2.8, snout 6.2, 6.4, interorbital 3.3, 3.4, in head. Jaws subequal anteriorly, a small elevation at the symphysis of lower jaw the most anterior point of the fish. Maxillary extending to below 0.8 of eye; the width of its free end about 0.8 distance from tip of upper jaw to level of orbit, subequal to pupil. Teeth in upper jaw minute, but tolerably

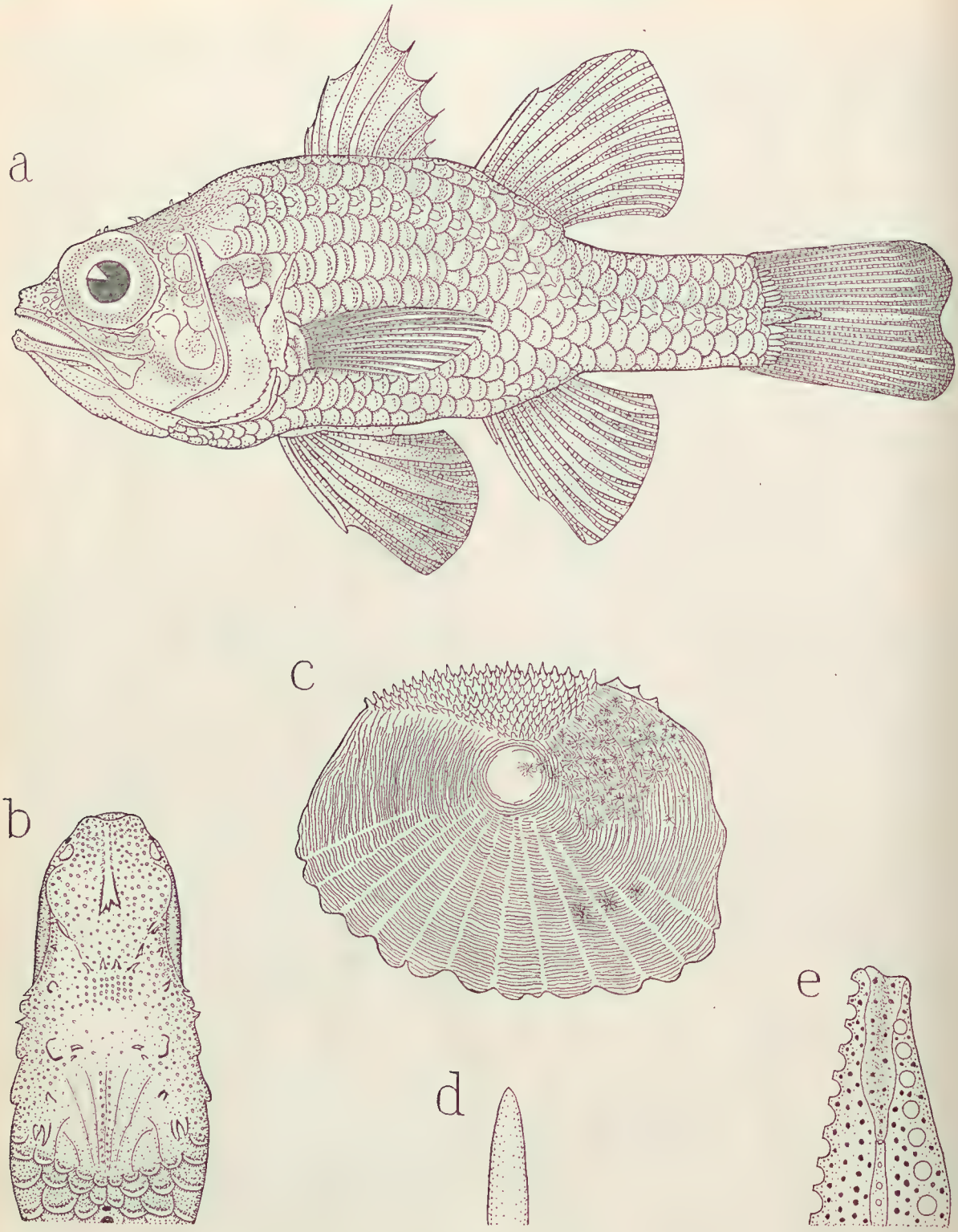

FIG. 1.—*Vincentia lemprieri* (Johnston), 1883. Specimen, standard length, 73.0, total length, 91.1 mm, from near *Akaroa*, near St Helens, George Bay, Cornwall, Tasmania; netted (Mr C. Burrows). *a.*—Lateral aspect (some detail of vertical fins conjectural); × 1½. *b.*—Head, dorsal aspect; ×2. *c.*—Scale from flank; × 15. *d.*—One of a series of about 14 lanceolate scales partly overlapping bases of major caudal rays; × 8. *e.*—Specialized posterior terminal scale of lateral line; × 8.

stout, subconical: in a band on either side (a brief hiatus between them at tip of jaw), thickly set in about 6-8 rows anteriorly; width of bands decreasing posteriorly (more rapidly in (*a*)), to cease at about an eye-diameter before end of maxillary. In lower jaw much the same; with a slightly tumid hiatus that fits into non-dentigerous region of upper jaw; length of chord of band subequal to eye. Teeth on vomer rather smaller than those in jaws; in a bell-shaped band, whose maximum width, occurring mesially, is less than greatest width of jaw-band. Teeth on palatines small, in a brief narrow series. Gill rakers on anterior arch 3 + 12: slender, subcylindrical (except lowest one or two, which are stouter, subconical); maximum length, occurring at upper end of lower limb (above which, on upper limb, length does not decrease greatly; but below which, on rest of lower limb, there is a regular decrease in height to one-fourth, or less), equal to about half eye. On 2nd, 3rd, 4th, arches rakers successively shorter, relatively stouter.

Tongue whitish; stout; broadly ovate, with well-developed median lobe, behind which it begins to become adnate; upper surface of lobe slightly convex transversely, more so anteroposteriorly; immediately behind lobe, profile rises sharply, owing to presence of paired mounded regions, beyond which profile becomes subhorizontal; upper surface somewhat complex, but without papillae; edentulous.

After its first few scales (where, noticeably in (*a*), it is nearer dorsal profile than elsewhere) the lateral line runs almost exactly parallel with the dorsal profile, except that it maintains its even curve below the dorsal bases, which (notably first dorsal) introduce into the profile local approximations to rectilinearity. At level of vent, it is about 2½ times as far from lower as from upper contour (measuring vertically); at middle of caudal peduncle, a trifle near dorsal profile (*a*), or equidistant from profiles (*b*).

Body covered with large ctenoid scales (Fig. 1 *e*). On breast a triangular area with 5-6 scales anteroposteriorly; at bases of pelvics in a transverse row of about 4, with 1 specialized elongated (in its exposed portion lanceolate) median scale, overlapping bases of the inner 2 or 3 pelvic rays. Normal scales extend for about 3 rows on to caudal base behind level of origin of first small outer caudal rays; being followed by 1 row of about 14 very narrow lanceolate scales partly overlapping bases of major caudal rays, their free tips being mostly in the interspaces between the rays (Fig. 1 *d*). Last scale along lateral line a specialized one; long, pennant-like, with about 8 pores along each border and a larger pore or partly open tube at tip (Fig. 1 *e*). Whole opercular region squamous; scales in 3-4 rows between orbit and angle of preopercular ridge. Dorsum of nape and head forward from a point in advance of first dorsal spine by a distance less than length of that spine; lateral surface above level of orbit to about an eye-diameter behind orbit; ventral surface of head; narrow half-annulus bordering eye inferiorly, all naked. Naked areas, except ventral surface of head, with small pores, most abundant on dorsum where there are upwards of 500. Much larger pores include: 1 on orbital border at 5 o'clock (left side of fish viewed), 1 between nostrils, 2 pairs (1 pair ventral, 1 facing forward) at tip of lower jaw.

Most of hind and lower margins of preoperculum denticulate. Preopercular ridge and preorbital entire. Operculum without spines: near its posterosuperior angle a small, broad, short, bluntly rounded lobe; below this a small elongate, narrow, distally rounded, flattened fleshy flap, about 2 long, directed towards base of first dorsal. Orbital rim smooth sharp well developed between 2 o'clock, where it throws in on to the dorsum a short process running obliquely forward, and 10 o'clock, where it forms 1 or 2 flattened processes, below which, after decreasing somewhat in altitude, it continues as a narrow wall, scalloped, in parts jagged, to 6 o'clock, thereafter lower, smoother (in first half of this section its general course more nearly rectilinear) to 2 o'clock, giving off, on the way, at 3.30 a hemispherical process, more pronounced in (*a*). A median ridge, bifurcating in its hinder ¼, ⅓, along dorsum of head from near snout-tip to level of anterior ¼, ⅓ of eye. On either side of the hinder part of this ridge, the relevant region partly bounded anteriorly by the the inward spur from orbital rim at 2 o'clock, interorbital is mesially concave. In (*a*) both the posterior rami of the median project (in (*b*) only the left projects) as sharp bony blades. Other elevations, trenchant or acute, covered, in part or wholly, with integument, or bare include: (*i*) a pair of curved ridges, originating about at level of middle of eye, internal to orbit by about their own length (in (*a*) right ridge simple, left bilobate; in (*b*) right in 2 separate elements); (*ii*) a little anterior to level of hindmost point on orbit a line of 4 points across mesial ⅓ of dorsum; (*iii*) on either side, at about vertical level of highest point on orbit a line of 4, extending over rather more than a eye-diameter, the first, shortly above orbit at 11 o'clock, a lanceolate blade, running forwards and downwards, its free border anterior, the second, a subhemispherical blade, free border behind and below; the third a blade with one free gently curved border, facing downward, the fourth, somewhat below level of rest, comprising 2 blade-like lips bordering a subhorizontal long linear opening; (*iv*) between fourth of (*iii*) and uppermost point of preoperculum (which is itself here trenchant), 2 small blades, the free edge of the hinder and upper standing out nearly at right angles to the general surface, the free edge of the lower directed more downwardly; internal to third of (*iii*), about along junction of lateral and superior surfaces of body, 2, the anterior, larger directly above the other just caudad of, third of (*iii*) (Fig 1 *b*).

Hinder part of dorsum of head and whole of nape with longitudinal ridges. In (*a*), in which they are more pronounced, they include: a median ridge (largest of the series) extending from about level of hinder ¼ of eye to base of first dorsal spine; on either side of this 4 ridges, following the same general course but shorter, gently sigmoid, the whole series (both sides) having a total width anteriorly of about ½ eye-diameter; a sigmoid ridge, arising near anterior origin of the most internal of the paired ridges just mentioned, and running back, through about an eye-diameter, to

overarch commencement of lateral line; a less-elevated curved ridge, originating lower down on lateral surface, and more anteriorly (close to orbit), and proceeding back subparallel to last-noted ridge throughout most of length of latter.

First dorsal: 1st spine small, its length 0.3 of second, which is 0.6, 0.5 of 3rd, the longest, exceeding eye + snout, 1.2 times 4th; stoutest is 3rd, followed in sequence by 4th, 2nd, 5th, 1st, 6th, 7th; base of fin slightly less than, slightly greater than, eye. Interdorsal 0.3, 0.4 of first dorsal base. Second dorsal: spine subequal to penultimate ray, subequal to 4th spine of first dorsal; fin somewhat higher than first dorsal; base 0.9, 0.7 of base of first dorsal. Anal: 1st spine 0.3 2nd, the latter longer than 2nd, shorter than 4th, of first dorsal; lower than second dorsal; base 1.1, 1.0 of base of second dorsal; originating below 1st, 2nd dorsal ray; last 3 rays inserted behind level of second dorsal termination. Caudal slightly emarginate, with rounded lobes; its length subequal to length of caudal peduncle. Pectoral obliquely truncate; longest (5th) ray exceeding eye + snout, subequal to twice interorbital; extending to level of 2nd anal ray. Pelvic inserted just in advance of pectoral; 1st 3 rays subequal (2nd barely longest), all longer than rays in any other fin; extending to 2nd anal spine. Caudal peduncle: depth a trifle greater than eye-diameter, 2.0, 1.8 in its own length.

Proportions.—The principal dimensions are set out as thousandths of standard length, *TLs*, in Table V. Since Johnston's 'total length' is likely to be more strictly comparable with our similarly designated measurement than is his 'length of body' with our 'standard length,' the dimensions of Mr Burrows' specimens are given also as thousandths of total length, *TLt*, for comparison with those of the holotype reduced to the same form.

Johnston recognized only 6 dorsal spines, recording their lengths, in sequence, as 7, 16, 15, 13, 8, 3mm. In making the calculations for the present table, and throughout the discussion generally, it is assumed that he failed to observe spine I and that these are actually the measurements of spines II-VII. There are good grounds for this course: (*a*) a small or very small 1st spine is normal in this family, its length in Australian species of genera clustering round the present form (*Gronovichthys, Vincentia, Lovamia, Apogonichthys*) being contained at least 3 times in length of longest spine; (*b*) in our specimens I is small and easily overlooked; (*c*) matching Johnston's measurements against those for spines II-VII of our (*a*) (8.1, 14.0, 11.5, 9.4, 6.7, 2.4) and of our (*b*) (8.6, 16.0, 13.0, 10.7, 6.9, 3.0) we find, for (*a*), $r = 0.97$ ($z = 2.17$), $t = 8.61^{**}$, for (*b*), $r = 0.96$ ($z = 1.96$), $t = 6.96^{**}$; (*d*) the relation for spine-length, $L_N = L_3 - dNk$ (see next section), found for spines IV-VII of our material is valid for the measurements of the holotype, if the first dimension recorded is that of spine II (see Table VI).

Coloration.—There are some differences between the specimens, particularly in the body, which in (*a*) bears some obscure dark markings not developed in (*b*).

(*i*) *Head.*—General color: very dark brown on dorsum, continuing to nape, where it is a trifle darker. Dark brown bar (convex upwards on left side of (*b*), otherwise virtually straight) from between 5 and 6 o'clock (left side viewed) on orbit to slightly below lower angle of preopercular ridge, subcontinuous anteriorly with an imperfect suborbital stripe running forward to nostril. Short, relatively broad spoke-like bars from orbit at 2 and 3 o'clock, former reaching to upper angle of preopercular ridge, and extending, continuously, or with brief interruption, in the same sense, for an equal or greater distance, length of whole marking about ⅔ eye-diameter. Lobe of operculum immediately behind preopercular border (in same general sense as ocular spoke at 3 o'clock) with one or more dark markings: in (*a*), on left, 3, the hindmost somewhat above, the middle largely below, the anterior; on right only the 2 more anterior, partly confluent; in (*b*), on left, well-formed V-shaped dark marking, directed forwards; on right, 2 small well-separated spots. In (*a*) left operculum with 3 or 4 small dark brown spots, and left preoperculum with half a dozen smaller spots, neither set well developed on right: both absent in (*b*). Upper jaw narrowly bordered with blackish, the line extending (*a*) to, or (*b*) nearly to, free tip of maxilla. Lower jaw bordered, a trifle more broadly than upper, with brown. Iris darkish and/or silvery with fine brownish punctulations. Lower surface with, in (*b*) a few, in (*a*) many, punctulations: in (*a*) only, an obscure longitudinal line of 4 or 5 brownish splashes on each side. Brilliant iridescent bluish (most conspicuous), purplish, and gold (most restricted) all over opercle.

(*ii*) *Body.*—On side below lateral line, most (*a*), or almost all (*b*) scales back to level of vent or beyond with inframarginal brownish arcs, and with some reddish brown peppering; recognizable bands persisting caudad of anal base only on right of (*a*). On side above lateral line, in advance of dorsal termination, the brownish becomes more extensive, occupying from about ½ of scale in (*b*) to most, or whole, of scale in (*a*); behind dorsal the brownish reduces to not very pronounced inframarginal arcs. Reddish brown punctulation more intense above than below lateral line. Bluish or purplish sheen on most of trunk below lateral line: ground color brownish yellow. Flank of (*b*) without special markings: that of (*a*) with a score or more small irregular very dark brown blotches below lateral line in advance of anal termination; the main concentration of pigmentation forming a rather ill-defined backwardly convex arc (better developed on left) extending from above upper angle of operculum to pass down, nearly to mid-ventral line, at level of middle of length of pectoral. Dorsal surface very dark on nape, dark or darkish along dorsal base, lighter, concolorous with flank, on caudal peduncle. Ventral surface more or less concolorous with lateral, except immediately in front of pelvic base, where it is lighter.

(*iii*) *Fins.*—What remains of membrane of first dorsal is translucent, heavily peppered, especially between the hinder spines, with red brown; 2 or 3 small spots between spines VI and VII. Basal remnants of membrane of second dorsal show more

TABLE V

Vincentia lemprieri (Johnston), 1883. Dimensions, expressed as thousandths of standard length (*TLs*), and as thousandths of total length (*TLt*), of 2 specimens (*a*) *Ls* 68.0 mm, *Lt* 86.9, (*b*) *Ls* 73.0, *Lt* 91.1, both from near St Helens, George Bay, Cornwall, Tasmania: also Johnston's data for the holotype, *Lt* 4 inches, expressed as *TLt*

Dimension	*TLs*		*TLt*		
	(*a*)	(*b*)	(*a*)	(*b*)	Holotype
Total length	1278	1248	—	—	—
Standard length (holotype: 'length of body')	—	—	782	801	800
Head	387	377	303	302	346
Snout	60	60	47	48	49
Eye	143	136	112	109	108
Interorbital	116	111	91	81	89
Length to middle of vent	596	610	466	468	
Length to origin of first dorsal	376	388	295	311	
Length to termination of first dorsal	543	555	425	445	
Length to origin of second dorsal	587	615	459	493	
Length to termination of second dorsal	706	734	552	588	
Length to origin of anal	618	629	483	504	
Length to termination of anal	751	748	588	619	
Length to pectoral origin	393	382	307	306	
Length of pectoral (total)	265	259	207	207	
Length of longest (5th, 5th) pectoral ray	240	227	188	182	
Length to pelvic origin	353	358	276	287	
Length of pelvic (total)	307	293	241	235	
Length of pelvic spine	184	164	144	132	
Lengths of pelvic rays 1-5 (holotype, 'longest')	280, 284, 280, 249, 207	260, 264, 260, 232, 193	219, 222, 219, 195, 162	209, 212, 209, 186, 155	207
Lengths of spines, I-VII of first dorsal (for assumption regarding holotype see text)	40, 119, 206, 169, 138, 99, 35	36, 118, 219, 178, 147, 95, 41	31, 93, 161, 132, 108, 77, 28	29, 94, 176, 143, 117, 76, 33	—, 69, 157, 148, 131, 79, 30
Length of spine of second dorsal	177	164	138	132	131
Lengths of rays, 1-8, of second dorsal: no entry, ray imperfect (holotype, 'longest')	—, 263, 252, 235, 222, 197, 173, 147	—, —, —, 233, 218, 193, 175, 122	—, 206, 197, 184, 174, 154, 136, 115	—, —, —, 187, 175, 155, 141, 98	187
Lengths of anal spines, I-II	44, 145	33, 123	35, 114	26, 99,	30, 187
Lengths of rays, 1-9, of anal: no entry, ray imperfect (holotype, 'longest')	—, 219, 222, 206, 191, 176, 168, —, 109	204, 202, 200, 180, 166, 164, —, 130, 110	—, 171, 174, 161, 150, 138, 131, —, 85	164, 167, 160, 144, 133, 132, —, 104, 88	187
Depth at anterior, posterior, border of eye	172, 331	164, 301	135, 259	132, 241	
Depth at opercular border, vent, termination of anal	397, 353, 184	370, 336, 178	311, 276, 144	296, 269, 143	
Depth at first dorsal origin, which is maximum depth (holotype, 'greatest depth)	404	384	316	307	346
Depth at caudal peduncle	150	151	117	121	

punctulation; rays greyish, darkening noticeably distally. Anal much like second dorsal, the tips of the rays less blackish. Pectoral pale grey, with some golden lights on rays. Pelvics briefly whitish basally, thereafter darkening—in (*a*) progressively to tip, where they are almost black; in (*b*) for more than half their length, beyond which they bear nearly a score of very narrow reddish brown cross bars, the interspaces being greyish. Caudal mostly light, faintly reddish brown, darkening somewhat in distal ⅓-½, the tips lighter.

Comparison with holotype.—(*i*) *Meristic characters.*—If, as has been suggested above, Johnston overlooked the 1st spine of first dorsal, meristic characters are in agreement. (*ii*) *Proportions.*—The 18 dimensions given for the holotype (some recorded in inches, some in millimetres) are exhibited in Table V, expressed as *TLt*. It will be seen agreement is in general satisfactory. In the Apogonidae the ratio of the lengths of the 2nd and 3rd dorsal spines is regarded as of diagnostic significance. (In 10 Australian species of *Gronovichthys* 6 are noted as having 3rd > 2 2nd, with 1 species noted as exhibiting each of these conditions; 3rd < 2 2nd, 3rd ≦ 2 2nd, 3rd ≒ 2 2nd, 3rd = 2-3 2nd). In (*a*), (*b*), holotype 3rd is 1.7, 1.9, 2.2 2nd. (*iii*) *Coloration.*—The holotype was stated to be 'uniformly brownish,' but, as noted above, though our specimens are not wholly unornamented, the markings are small and relatively inconspicuous. Two of the fins reported by Johnston as light reddish (anal, caudal) exhibit in our material some distal darkening. (*iv*) *General morphological features.*—General features recorded in the short description of the holotype are in good agreement with those observed in Mr Burrows' specimens.

It may be regarded as highly probable that the present material does indeed constitute a recovery, after upwards of three-quarters of a century, of Johnston's *Apogon lemprieri* and a confirmation of its specific distinctness.

Generic status.—Since the publication of the Check List (McCulloch, 1919) the taxanomic position with regard to the Australian members of the Apogonidae has undergone considerable revision. The Handbook (Munro, 1960) recognizes 16 genera as follows (number of Australian species in parentheses): (*i*) *Apogonops* Ogilby, 1896 (1); (*ii*) *Dinolestes* Klunzinger, 1872 (1); (*iii*) *Gymnapogon* Regan, 1905 (1); (*iv*) *Cheilodipterus* Lacépède, 1802 (1); (*v*) *Paramia* Bleeker, 1863 (1); (*vi*) *Siphamia* Weber, 1909 (6); (*vii*) *Archamia* Gill, 1863 (1); (*viii*) *Epigonus* Rafinesque, 1810 (1); (*ix*) *Apogon* Lacépède, 1802 (5); (*x*) *Glossamia* Gill, 1864 (2); (*xi*) *Kurandapogon* Whitley, 1939 (1); (*xii*) *Pristiapogon* Klunzinger, 1870 (1); (*xiii*) *Gronovichthys* Whitley, 1929 (11); (*xiv*) *Vincentia* Castelnau, 1872 (1); (*xv*) *Lovamia* Whitley, 1930 (7); (*xvi*) *Apogonichthys* Bleeker, 1854 (8).

From all Australian species of (*i*), (*ii*), (*iii*), (*iv*), (*v*), (*vii*), (*ix*), (*x*), (*xi*) Mr Burrows' fish is at once distinguished by a different (except in the case of (*i*) a greater) number of spines in first dorsal; from (*vi*) by the absence of a lateral subcutaneous gland; from (*viii*) by the presence of a preopercular ridge; from (*xi*) and (*xv*) by color pattern; from (*xvi*) by shape of caudal. We are left with *Gronovichthys* and *Vincentia*: the relation between these genera and the validity of the second—problems that appear in the Handbook to have received neat solution—are acutely brought in question by the present material.

In the original diagnosis (Castelnau, 1872 *b*: 245) *Vincentia* was defined as having, *inter alia*, (*i*) dorsals separate ('its two dorsals are inserted the one very near the other'; again, later, 'two dorsals'; also 'general characters of *Chilodipterus* [*sic*] . . .'), (*ii*) palatines lacking teeth: type species, *V. waterhousii*, with sole notation 'reddish colour'. The genus was subsequently further discussed and rediagnosed (1873 *b*: 59), additional points in the new account being: (*a*) teeth now described as villiform in both jaws; (*b*) no canines; (*c*) 7 branchiostegals; (*d*) operculum denticulated; (*e*) scales large, adherent: the notation regarding the dorsal still reads 'two dorsals placed one near the other'. In the new, full account of *V. waterhousii* teeth are expressly noted as being absent from the vomer, 'but the pharyngeal bones are covered with small granular teeth': 'the second dorsal almost touches the first'. In the Check List *V. waterhousii* is synonymized with *Apogon conspersus* Klunzinger, 1872.

The establishment by Whitley of *Gronovichthys* [first published as a footnote (1929: 305), to replace *Amia* Gronow, 1703, non-binominal = *Amia* Meuschen, 1871 preoccupied; with diagnosis later (1930: 11)] and of *Lovamia*, 1930 has in the Handbook provided accommodation for 18 species, of which 15 had appeared in the Check List under *Apogon* (2 of them as synonyms), 1 under *Apogonichthys*, with 2 not noted. The present problem is largely concerned with the generic status of *Apogon novaehollandiae* Valenciennes, 1832 (which in the Check List remains in that genus), which differs from the 18 species just referred to in having the dorsals united. Whitley, rehandling Castelnau's genus *Vincentia* in 1930, defined it thus, '*Vincentia* may be distinguished from *Lovamia* and *Gronovichthys* by its united dorsals and the much greater depth of the body, the depth being greater than length of head or about one-third total length': agreeing with the Check List, he treats the holotype, *V. waterhousii* as synonymic with *Apogon conspersus* Klunzinger, 1872. As the Handbook synonymizes *A. conspersus* [together with *A. waterhousii* Castelnau, 1872, *A. guntheri* Castelnau, 1872, *A. lemprieri* Johnston, 1883 and *Mionorus ramsayi* Fowler, 1908] with *A. novaehollandiae*, the the latter species appears in it as a *Vincentia* (sole species of the genus). Castelnau's genus, established for a species with edentulous palatines (and vomer?) and having 2 separate dorsals thus becomes (via the synonymization of its type species with a species having the characters just to be mentioned) a respository for a form possessing toothed palatines and vomer and differing from all its immediate allies in having the dorsals united.

Regarding the 2 characters on which *Vincentia*, as now interpreted, is based, it may be noted: (*a*) at least one genus in this family, *Apogonichthys*, includes one species, *A. ahimsa* Whitley, 1959, that differs from the remaining Australian species in

having the dorsals united; (*b*) depths exceeding length of head and more than one-third total length are encountered in species ascribed in the Handbook to *Gronovichthys*.

Examination of the present material leaves me with a strong feeling that Mr Burrows' fish, in spite of its separate dorsals, is congeneric with the species occurring as entry 901 in the Handbook (Munro, 1960: 144) under the designation *Vincentia novaehollandiae* (Valenciennes), 1832. Whether these two species should remain in *Vincentia* or whether one or both of them should be relegated to *Gronovichthys*, is a problem regarding the solution of which I have arrived at no firm opinion. It should be remarked that in the Handbook the lateral line of Valenciennes' species is noted as being continued to tail base 'here it ends in a long pointed scale which has about 5 pores along upper and lower edges and a larger one terminally.' This observation, which does not appear in the Handbook for any species of *Gronovichthys*, is applicable also to the present species, and the possibility arises that this shared feature, if it is, indeed, lacking in other forms, may conveniently be taken as marking off this two species generically.

Specific affinities.—If Johnston's species remains in *Vincentia*, it is at once distinguished from *V. novaehollandiae* by its separate dorsals and by its much broader interorbital: apart from these features, it approximates that species more closely than it does any species of *Gronovichthys*. The teeth of *V. novaehollandiae* are stated to be 'fine, villiform': those of the present form may be described as small, conical. The occurrence within a single genus of species with these two kinds of teeth is paralleled in *Gronovichthys*.

If *Vincentia* is to stand as a genus characterized by separate dorsals and the present species is relegated to *Gronovichthys*, it will be adequately segregated by the subjoined tabulation, which notes at least 2 points of difference between it and each of the Australian species of that genus, with the exception of *G. rudis* (De Vis), 1884, imperfectly known from a single specimen (that species has interorbital 4.5, snout 5, in head: the Tasmanian species 3.4-3.5, 6.3-6.9). The following appear in the Handbook (the catalogue-numbers being retained for convenient reference below): 890, *G. aureus* (Lacépède), 1802; 891 *G. chrysurus* (Ogilby), 1889; 892 *G. atripes* (Ogilby), 1916; 893 *G. darnleyensis* (Alleyne & Macleay), 1877; 894 *G. cpercularis* (Macleay), 1878; 895 *G. ruppelli* (Günther), 1859; 896 *G. brevicaudatus* (Weber), 1909; 897 *G. bandanensis* (Bleeker), 1854; 899 *G. rudis* (De Vis), 1884; 900 *G. punctatus* (Klunzinger), 1879.

With A. II, 9 our species differs from 890, 891, 892, 893, 896, 897, 898 (all with A. II, 8) and 900 (II, 10-11). Orbital rim [partly scalloped] entire in 893, 894 (?), 895, 897, 898. Caudal [emarginated] truncate or rounded in 891, 892, 893. Pelvics [to 2nd anal spine] failing to reach anal in 894, 896, 897. Gill-rakers on lower limb of anterior arch [12] exceed 16 in 890, 897, 898. Eye [2.2-2.4 snout] $<$ 2 snout in 890, 891, 892, 894, 895, 896, 897, 900. The color pattern of Johnston's species approaches that of *Vincentia novaehollandiae* more closely than it does that of any species of *Gronovichthys*, the divergence being most notable in 890, 892, 896, 897, 898, 899.

Length pattern of spines of first dorsal.—The lengths of the spines of the first dorsal follow, with significant fidelity, a simple pattern: first, for the anterior suite of spines (1st-3rd), in which spine-length increases caudad, the logarithm of of length of spine is a linear function of serial number of spine; while, secondly, for the posterior suite of spines (4th-7th), in which spine-length decreases caudad, it is the logarithm of the difference between length of longest spine (3rd) and length of spine considered that is a linear function of the spine's (total) serial number. That is, with L = length of spine, and N (whether used as on-the-line symbol or as suffix) = serial number of spine, we have for the anterior spines

$$\log L_N = k \log N + \log d \qquad (i)$$

or $$L_N = d\, N^k \qquad (ii)$$

For spines I, II, III of specimen (*a*) (lengths in mm) the best straight line (squares of the departures of the estimated logarithmic values from the actual logarithmic values a minimum) is

$$\log L_N = 1.5071 \log N + 0.4377 \qquad (iii)$$

with $t = 21.94^*$. For (*b*) the corresponding equation is

$$\log L_N = 1.6617 \log N + 0.4202 \qquad (iv)$$

with $t = 32.23^*$. For spines IV, V, VI, VII the general equation is

$$\log (L_3 - L_N) = \mathrm{k} \log \mathrm{N} + \log \mathrm{d} \qquad (v)$$

or $$L_N = L_3 - d\, N^k \qquad (vi)$$

For specimens (*a*), (*b*) the best straight lines are, respectively

$$\log (L_3 - L_N) = 2.6504 \log N - 1.1892 \qquad (vii)$$
$$\log (L_3 - L_N) = 2.6564 \log N - 1.1235 \qquad (viii)$$

with $t = 6.38^*$, 35.33^*, respectively.

If the assumption (see above) that the lengths of the spines of the holotype recorded by Johnston as those of I-VI are those of II-VII be accepted, the length pattern for the hinder series of spines found for our material continues to hold good; though the parameters of the equation differ noticeably from those of equations (*vii*), (*viii*)—the best straight line being

$$\log (L_3 - L_N) = 4.6891 \log N - 2.8048 \qquad (ix)$$

with $t = 9.21^*$.

Granted the establishment, at an acceptable degree of statistical significance, of the formal relation, the systematist may be presumed to be interested to learn the measure of agreement between values predicted by such equations and spine-lengths as measured. It may be noted that a somewhat better estimation of absolute lengths than that yielded by the procedure adopted above can usually (though here in only 2 of the 4 instances) be obtained by calculating the equation for the line fitted under the condition that the sum of the squares of the absolute (instead of the logarithmic) residuals will be a minimum. For specimen (*a*) the two such equations are

$$\log L_N = 1.4257 \log N + 0.4682 \qquad (x)$$
$$\log (L_3 - L_N) = 2.7878 \log N - 1.2943 \qquad (xi)$$

and for (*b*)

$$\log L_N = 1.5845 \log N + 0.4495 \quad (xii)$$
$$\log (L_3 - L_N) = 2.9556 \log N - 1.3649 \quad (xiii)$$

For Johnston's data, with the same assumption made as for (*ix*), the equation corresponding to equations (*xi*) and (*xiii*) is

$$\log (L_3 - L_N) = 3.8437 \log N - 2.1257 \quad (xiv)$$

Spine-lengths, as measured, and as estimated from the above equations are set out in Table VI. Though no further investigations along these lines have been carried out, it would seem not improbable that comparably simple and elegant relationships may characterize spine-length in some other fishes.

TABLE VI

Vincentia lemprieri (Johnston), 1883. Lengths of spines (mm) of first dorsal; measured values and values estimated from 10 equations set out in text: 2 specimens from near St Helens, George Bay, Cornwall, Tasmania, and holotype (for assumption concerning the serial numbers of the spines of which see text)

Spine No.	Specimen (*a*)			Specimen (*b*)			Holotype		
	Measured	Estimated		Measured	Estimated		Measured	Estimated	
		Equations (*iii*), (*v*)	Equations (*x*), (*xi*)		Equations (*iv*), (*vi*)	Equations (*xii*), (*xiii*)		Equation (*ix*)	Equation (*xiv*)
I	2.7	2.7	2.9	2.6	2.6	2.8	—	—	—
II	8.1	7.8	7.9	8.6	8.3	8.4	7	—	—
III	14.0	14.3	14.0	16.0	16.3	16.1	16	—	—
IV	11.5	11.4	11.6	13.0	13.0	13.4	15	15.0	14.5
V	9.4	9.4	9.5	10.7	10.6	11.0	13	13.0	12.4
VI	6.7	6.7	6.5	6.9	7.2	7.4	8	9.0	8.7
VII	2.4	2.8	2.5	3.0	2.8	2.4	3	1.6	2.7

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ON ATRAX INFENSUS SP. N. (ARANEIDA: DIPLURIDAE) ITS HABITS AND A METHOD OF TRAPPING THE MALES.

By

V. V. Hickman

(With 2 plates and 5 figures in the text.)

ABSTRACT

A key to the Australian spiders belonging to the genus *Atrax* O. P. Cambridge is provided and a new species, *Atrax infensus*, from Queensland described. An account of its nest, food and mating habits is also given. A trap employed in the capture of the males is figured and described.

INTRODUCTION

In January this year Mr. P. Walker of Toowoomba, Queensland, sent me three males and four females of a funnel-web spider for identification. All the specimens were mature and proved to belong to a new species in the genus *Atrax* O. P. Cambridge. Mr. Walker, who had made a careful study of the life of the spider, provided me with notes and photographs illustrating its habits. He also gave me a description of a trap, which he employed successfully in capturing the males. An account of the trap appears at the end of the present article.

It is well known that the venom of funnel-web spiders belonging to the genus *Atrax* may sometimes prove fatal to man. The nature of the venom of *Atrax robustus* O. P. Cambridge has been investigated by Dr. S. Wiener (1957, 1959 and 1961) and by Dr. G. H. Kaire (1963). The venom of the spider described in the present paper has also been studied by Dr. Kaire (1963).

The correct identification of the spiders belonging to the genus *Atrax* is obviously of considerable importance. However, much of the early systematic work is lacking in detail and of little help in determining species.

Cross-mating experiments, as carried out by Mr. Walker in the case of the spider from Toowoomba, are most desirable in order to determine whether males and females belong to the one species. Such experiments are very necessary where females of different species closely resemble one another.

Including the new species, *Atrax infensus*, described in the present paper, nine species of funnel-web spiders belonging to the genus *Atrax* are known. They are listed in Table 1.

Table 1.

Species	Sexes known	Distribution
A. robustus O. P. Cambridge 1877	♂, ♀	New South Wales, Victoria
A. modestus Simon 1891	♀	Melbourne (Museum)
A. formidabilis Rainbow 1914	♂, ♀	New South Wales, Queensland
A. versutus Rainbow 1914	♀	New South Wales
A. bicolor (Rainbow) 1914	♀	New South Wales
A. validus Rainbow & Pulleine 1918	♀	Queensland
A. venenatus Hickman 1927	♂, ♀	Tasmania, New South Wales
A. pulvinator Hickman 1927	♀	Tasmania
A. infensus sp. n.	♂, ♀	Queensland

Atrax bicolor was originally described under the name *Aname bicolor* by Rainbow in 1914 and transferred to the genus *Atrax* by him in 1918. In the original description the species is said to have "two basal combs" on the superior tarsal claws. If this is correct the spider differs from all other known species of *Atrax*. The male of *Atrax robustus* Cambridge was described as a new species, *Euctimena tibialis*, by Rainbow (1914) and the synonymy established by Musgrave (1927).

It will be seen from Table 1 that, although females of all the species are known, males have been recorded in four cases only. A detailed account of the female of *A. formidabilis* does not appear to have been published, although McKeown (1963) gives a brief description of a specimen from the McPherson Range, New South Wales.

The distinctive features of a large female example of *Atrax formidabilis* from Dorrigo, N.S.W., given to me by Mr. N. L. Roberts and a co-type of *Atrax validus* on loan to me from the Australian Museum have been utilised in the following key.

Family DIPLURIDAE

Genus ATRAX O. P. Cambridge

KEY TO FEMALES

1. Upper tarsal claws with two rows of teeth ..... *A. bicolor* (Rainb.).
   Upper tarsal claws with one row of teeth 2
2. Front row of eyes recurved ..... *A. versutus* Rainbow.
   Front rows of eyes straight or procurved 3
3. Patella of leg IV with spines 4
   Patella of leg IV without spines 5
4. Promargin of chelicerae with 5 teeth ..... *A. pulvinator* Hickman.
   Promargin of chelicerae with 10-18 teeth ..... *A. robustus* O. P. Camb.
5. Femur III with 4 prolateral spines ..... *A. formidabilis* Rainbow.
   Femur III without spines 6
6. Tibiae I and II without spines ..... *A. modestus* Simon.
   Tibiae I and II with spines 7
7. Tibia I with one spine ..... *A. venenatus* Hickman.
   Tibia I with three spines 8
8. Carapace brown with yellow hairs ..... *A. validus* Rainb. & P.
   Carapace black with fine black hairs ..... *A. infensus* sp. n.

KEY TO MALES

1. Tibia II with spur 2
   Tibia II without spur 3
2. Spur on Tibia III long and conical ..... *A. robustus* O. P. Camb.
   Spur on tibia III short and rounded ..... *A. formidabilis* Rainbow.
3. Tibia of palp with spines ..... *A. venenatus* Hickman.
   Tibia of palp without spines ..... *A. infensus* sp. n.

Atrax infensus sp. n.

Male. Holotype.

Total length with chelicerae 27.0 mm. *Carapace* 12.0 mm. long, 9.0 mm. wide, convex, high anteriorly and sloping gently from the ocular area to the posterior margin, which is emarginate. The colour in life is black and shining. Thoracic fovea transverse, deep, procurved and situated about 3/10 from the posterior margin. Cephalothoracic sulci distinct. The sides of the head clearly delimited. Its posterior limit is somewhat in advance of the thoracic fovea. The eye tubercle low and marginal in front. The eye-group is transversely rectangular in ratio 41 : 20. The first row of eyes is almost straight (Text-fig. 1). Ratio of eyes AME : ALE : PME : PLE = 10 : 10 : 5 : 8. The pupil of AME has a diameter of 6/10 that of the whole eye. PME are somewhat irregular in outline and white. The ocular quadrangle is wider behind than in front in ratio 25 : 20, and wider than long in ratio 25 : 18. The laterals are separated by 4/10 of the diameter of ALE. A group of short bristles is present on the eye-tubercle in front of AME and also behind them. The anterior margin is fringed with a few fine black hairs and bristles in front of the ocular region and for a short distance on each side of it. The margin of the carapace is yellowish brown and fringed with a few fine black hairs but without coarse bristles. A few short dark bristles form a middorsal row extending from the eye-group almost to the thoracic fovea. The surface of the carapace is clothed with a few short fine scattered dark hairs.

Chelicerae (Text-fig. 2) strong, without a rastellum, clothed on the dorsal surface with fine black bristles and short hairs. The bristles are larger and more numerous towards the front. Near the base the surface is almost bare. An elongate area towards the prolateral side of the dorsal surface is marked with a series of oblique ridges, which in conjunction with bristles on the palp may serve a stridulating function. The promargin of the furrow has a slight scopula and a row of 11 teeth. The retromargin has a denser scopula of reddish hairs and a row of 10 teeth. Between the two marginal rows there is an irregular intermediate row of about 25 very small teeth. The fang is dark reddish brown; long and well curved.

Labium is light reddish brown, convex, and wider than long in ratio 30 : 25. The entire ventral surface is covered with densely arranged cuspules. Long bristles are present in front, at the sides and behind.

Maxillae are light reddish brown and with parallel sides. The inner or prolateral side has a sharply produced distal angle. The entire promargin is furnished with a thick red scopula. Numerous cuspules form a group occupying a triangular area extending from the base for about

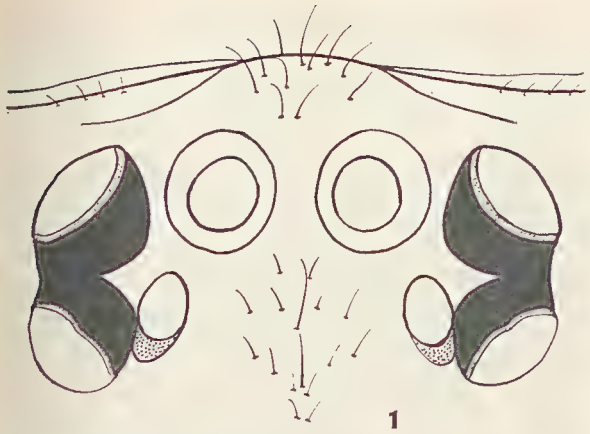

FIG. 1.—Eye-group of male.

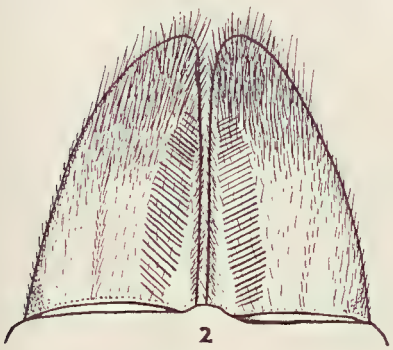

FIG. 2.—Dorsal view of chelicerae of male.

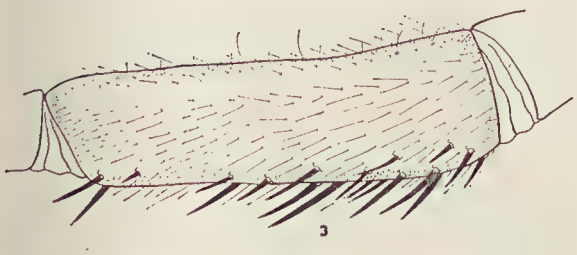

FIG. 3.—Retrolateral view of left tibia of second leg of male.

FIG. 4.—Retrolateral view of left palp of male.

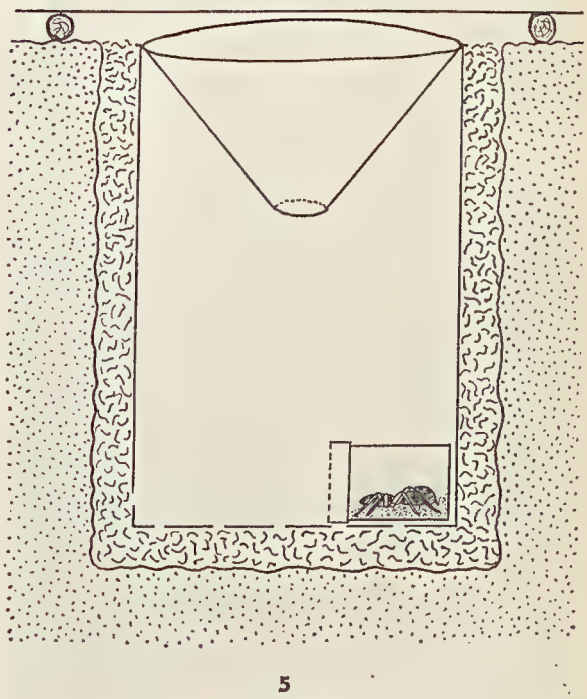

FIG. 5.—Diagram of trap used in capturing males of *Atrax infensus*.

5/7 of the length and situated on the proside of the diagonal from the distal inner angle to the basal outer angle. The surface is clothed with a few erect black bristles and fine reddish brown hair.

Sternum dark reddish brown with a yellowish margin, longer than wide in ratio 104 : 85. Lightly clothed with long erect black bristles and shorter erect hairs. Anteriorly the sternum is narrower and excavated round the base of the labium forming a procurved area devoid of hairs and bristles. Posteriorly the sternum ends in a point, behind which the fourth coxae are contiguous. Three pairs of sigilla are present and situated away from the margin, the posterior pair being large and elongate.

Legs 4. 1. 2. 3., concolorous with carapace and clothed with coarse hairs and bristles. Two longitudinal hairless bands are present on the dorsal surface of femora, patellae and tibiae. Femora of first pair of legs slightly bowed. Tibiae of second pair of legs devoid of a spur (Text-fig. 3). A dense pad of short hairs is present on the ventral surface of all tarsi and on the distal third of the ventral surface of the first, third and fourth metatarsi, but not on that of the second metatarsi. On the first and second tarsi the pad is bisected by a longitudinal row of short fine setae. Sensory hairs or trichobothria are present in a double row on all the tibiae and in a single row on metatarsi and tarsi. Three tarsal claws are present. The upper claws have about 11 teeth arranged in an oblique row; the lower claw about three. Measurements in millimetres of the segments of the legs and palpi are as follows:—

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	8.5	4.7	6.0	5.9	4.2	29.3
2	8.0	4.6	5.7	6.2	3.7	28.2
3	7.0	4.0	4.6	5.7	3.5	24.8
4	9.0	4.5	6.0	7.4	4.2	31.1
Palp.	4.8	2.6	4.6	—	3.4	15.4

Spines. First leg. Femur 0. Patella: prolateral 1; elsewhere 0. Tibia: ventral 5 at apex and about 27 large spines arranged irregularly along the whole surface and towards the retrolateral side; elsewhere 0. Metatarsus: ventral 4 at apex and about 28 arranged irregularly over the surface but being more numerous and longer in the basal half; elsewhere 0. Tarsus: ventral about 15 short spines in a longitudinal row on each side; elsewhere 0. *Second leg.* Femur 0. Patella: prolateral 1 near apex; elsewhere 0. Tibia: ventral 4 at apex and about 16 arranged irregularly along the whole surface and towards the retrolateral side; elsewhere 0. Metatarsus: ventral 4 at apex and about 20 arranged irregularly along the whole surface and towards the retrolateral side; elsewhere 0. Tarsus: ventral about 15 small spines in a longitudinal row on each side; elsewhere 0. *Third leg.* Femur 0. Patella: prolateral 1-1-2; elsewhere 0. Tibia: dorsal 0, prolateral 2-2-1 at apex, retrolateral 1-1; ventral 2-2-2 at apex. Metatarsus: dorsal 2 near apex, prolateral 1-1, retrolateral 1-1-1-1, ventral 2-2-2-4 apical. Tarsus: dorsal 0, prolateral 1 in distal third, retrolateral 0, ventral about 14 spines in a longitudinal row on each side. *Fourth leg.* Femur 0. Patella 0. Tibia: dorsal 0, prolateral 0, retrolateral 1 in distal third, ventral 1-3-1-3 apical. Metatarsus: dorsal 0, prolateral 0, retrolateral 1-1-1-1, ventral 2-1-1-2-2-2-2-4 apical. Tarsus: dorsal 0, prolateral 0, retrolateral 0, ventral about 16 small spines in a longitudinal row on each side.

Palpi concolorous with the carapace except the extremity of the tarsus, which is whitish. Clothed with fine hairs and coarse bristles. Two longitudinal bare patches are present on the dorsal side of femur, patella and tibia. Femur is strongly bowed. Spines are absent on all segments, but a group of strong bristles is present on the prolateral side of the femur near the apex. Numerous long erect bristles clothe the ventral side of the tibia The genital bulb is pyriform and produced into a long style, which is somewhat spatulate and twisted. The whole organ is about 4.3 mm. in length and almost as long as the tibia (Text-fig. 4).

Abdomen dull black with no visible pattern in the living spider. Clothed with fine erect black setae and recumbent hairs. Lung covers yellowish brown. The area on the ventral surface between the front pair of lung covers is light grey. Two pairs of spinnerets are present. They are brown above and grey below. The first pair are about 1.2 mm. long and separated from each other by a distance equal to their diameter. The second pair have three segments measuring 1.7, 0.9 and 1.8 mm. respectively. The whole abdomen is 12.0 mm. long and 9.0 mm. wide.

Female. Allotype.

Total length with chelicerae 33.0 mm. *Carapace* black and shining, 12.5 mm. long, 10.5 mm. wide, moderately high in front and sloping gradually from the eye region to the posterior margin. Thoracic fovea deep, transverse, procurved and slightly less than 1/3 from the posterior margin. Sides of head limited by the cephalothoracic sulci. Posterior limit of head not clearly marked, but appears to be slightly in advance of the thoracic fovea. Eye tubercle low and not sharply delimited. It is almost marginal in position. Eye-group transversely rectangular in ratio 45 : 22. First row of eyes almost straight, second row recurved. Ratio of eyes AME : ALE : PME : PLE = 9 : 11 : 7 : 8. Pupil of AME has a diameter 5/9 that of the eye. PME are somewhat irregular in outline and white. Ocular quadrangle wider behind than in front in ratio 30 : 20. Laterals separated by 5/11 of the diameter of ALE. A group of bristles is present in front of and behind AME. A few short setae on the front margin of carapace extend only a short distance on each side of the eye region, the greater part of the margin being bare. A middorsal row of long erect bristles extends from the eye region to the fovea. Surface of carapace has a light clothing of small recumbent hairs, which tend to be arranged in radial rows on the areas between the thoracic depressions.

Chelicerae black, powerful, without a rastellum, clothed with black bristles on the dorsal surface and with short hairs on the retrolateral surface. The oblique ridges present in the male are absent. Fang black, strong and well curved. The promargin of furrow with a row of 12 large teeth, the

retromargin fringed with a reddish brown scopula and provided with a row of about 10 large teeth. Between the two rows of large teeth there are about 48 small teeth, which tend to form a double row near the base but are arranged irregularly in the distal third (Pl. 1, fig. 1).

Labium convex, truncate in front, wider than long in ratio 47 : 40. Fringed with long reddish brown hairs in front, shorter hairs at the side and behind. Most of the surface is covered with numerous small cuspules densely arranged.

Maxillae with parallel sides and a sharply produced inner distal angle. A strong reddish brown scopula is present on the promargin. Numerous small cuspules occupy a triangular area extending from base almost to apex on the proside of a diagonal from the basal outer angle to the distal inner angle. The rest of the surface is clothed with erect dark bristles.

Sternum longer then wide in ratio 114 : 100, dark brown, lightly clothed with erect black bristles. Sigilla elongate and removed from the margin. Anteriorly the sternum is excavated round the base of the labium. Posteriorly it ends in a point in front of the fourth coxae, which are almost contiguous.

Legs 4. 1. 2. 3. Similar in colour to the carapace. Clothed with dark bristles and hairs. A pair of longitudinal bare patches on dorsal side of femora, patellae and tibiae. Tarsi and metatarsi without scopula and also without the pad of short hairs present in the male. Femora of first pair of legs slightly bowed. Trichobothria in two rows on tibiae and in a single row on metatarsi and tarsi. Three tarsal claws are present. The upper claws have about 9 teeth in an oblique row. The lower claw has 3 teeth. The measurements in millimetres of the segments of the legs and palpi are as follows:—

Leg	Femur	Patella	Tibia	Metatarsus	Tarsus	Total
1	8.0	5.2	4.9	4.8	2.6	25.5
2	8.0	4.9	4.5	4.6	2.6	24.6
3	6.5	4.4	3.7	4.3	2.8	21.7
4	8.0	5.0	5.3	5.4	2.7	26.4
Palp	6.0	3.1	3.1	—	4.0	16.2

Spines. First leg. Femur 0. Patella 0. Tibia: dorsal 0, prolateral 0, retrolateral 0, ventral 1 near middle and towards the promargin and 2 apical. Metatarsus: ventral 1-1 on promargin, 5 on retromargin, 1-1 midventral, 3 apical, elsewhere 0. Tarsus: a row of 5 on each side of ventral surface, elsewhere 0. *Second leg.* Femur 0. Patella 0. Tibia: dorsal 0, prolateral 1 in distal half, retrolateral 0, ventral 1 near middle and 2 apical. Metatarsus: ventral 5 along retromargin, 1-2 on promargin and 5 apical; elsewhere 0. Tarsus: a row of 4 on each side of ventral surface, elsewhere 0. *Third leg.* Femur 0. Patella: dorsal 0, prolateral 6, retrolateral 1, ventral 0. Tibia: dorsal 0, prolateral 1 apical, retrolateral 1-1, ventral 2 apical. Metatarsus: dorsal 0, prolateral 1-1-1, retrolateral 1-1, ventral 2-3-1r-4 apical. Tarsus: dorsal 1 in distal half, prolateral 1-1, retrolateral 0, ventral a row of three on each side. *Fourth leg.* Femur 0. Patella 0. Tibia: dorsal 0, prolateral 1 apical, retrolateral 1 in distal half, ventral 2 apical. Metatarsus: dorsal 0, prolateral 1-1-1 apical, retrolateral 0, ventral 2-2-2-2-4 apical. Tarsus: dorsal 0, prolateral 1 in distal half, retrolateral 0, ventral a row of 6 on each side.

Palpi similar in colour and clothing to the legs. Femur strongly bowed. Spines are arranged as follows:—Femur 0. Patella 0. Tibia: dorsal 0, prolateral 0, retrolateral 0, ventral 3 apical. Tarsus: dorsal 0, prolateral 5, retrolateral 4, ventral 2 near apex. Trichobothria are present on tibia and tarsus. The tarsal claw has about 6 teeth.

Locality. Toowoomba, Queensland. Specimens collected by Mr. P. Walker in January, 1963.

Affinities. Atrax infensus sp. n. is undoubtedly more closely related to the Tasmanian species *Atrax venenatus* than it is to *A. robustus* and *A. formidabilis.* In the two latter species the males possess a spur or apophysis on the ventral side of the tibiae of the second pair of legs. Such a tructure is absent in the males of both *A. infensus* and *A. venenatus,* which bear a close resemblance to each other in general appearance. However, *A. infensus* differs from *A. venenatus* in (1) size, (2) relative length of genital style, (3) absence of spines on palpi of male, (4) arrangement of the spines below the tibiae of the second pair of legs of the male, and (5) relative proportions and spacing of the eyes.

NEST, HABITS AND EGG-SAC

The following notes are based mainly on observations made by Mr. P. Walker:—

The burrow made by females and immature males may be excavated to a depth of 62.0 cm. (2 feet). The spider seems to favour powdery red laterite soil in open forest country, but sometimes the nest is made in heavier soils. A silk lining, which is not attached to the walls but hangs freely in the burrow, extends for the full length of the nest. In the breeding season a brood chamber is excavated near the bottom of the burrow in order to accommodate the egg-sac. When the young spiders emerge from the egg-sac, a second brood chamber is made somewhat further down. In this second chamber the young ones congregate and remain with the mother for a considerable time. At the surface of the soil the silken tube which lines the burrow forms one or more funnel-like openings (Pl. 1, fig. 2). In most cases two such openings are made but in some cases four. A series of trap-lines radiate from the lower margin of each opening and tend to entangle the feet of ground roving insects. The upper part of the funnel lies flat against the lower part, thus closing the entrance.

After devouring its prey the spider generally removes any remnants from the burrows and deposits them in a heap near the funnel-like openings to the nest. One such heap, which I examined, contained remains of beetles, ants, bugs, spiders numerous millipedes, several land snails and a small lizard. There is no doubt that the spider had actually fed on the lizard, since the remnants, consisting of scales and broken bones, were in the form of a well masticated lump.

The mating season appears to be of short duration, probably about two months, usually November and December. The position adopted by the male and female during copulation resembles that of *Avicularia metallica* as described by Bonnet (1930). The pair face each other and the female leans back with the four front legs elevated (Pl. 2, fig. 3). She remains in this position during the process and for some time afterwards. Immediately after mating the male spends some time rubbing his body with his legs, as if going through an elaborate cleaning operation. On two occasions Mr. Walker witnessed the mating behaviour of specimens of *Atrax infensus* kept in captivity. The female made no attempt to attack the male although the two were kept in the same container for several days.

The egg-sac (Pl. 2, fig. 4) is white and more or less pillow-shaped. It measures about 40.0 mm. long and 35.0 mm. wide and is suspended by its corners from the silk lining of the first brood chamber in the burrow. The egg-sacs are made in December and January. One which I examined on 18th February contained 250 young, some of which were already emerging from the sac.

Some observations on the habits of *Atrax robustus* have been recorded by Wakefield (1958), Wiener (1959) and Levitt (1961) but little is known concerning the habits of other described species.

TRAP FOR CAPTURING MALES OF ATRAX INFENSUS

A trap designed by Mr. Walker and used successfully in capturing the males of *Atrax infensus* is shown in text-fig. 5. It consists of a tin about 21.0 cm. in diameter and 31.0 cm. deep. The lid is removed and replaced by a funnel, which is about one-third the depth of the tin. The funnel fits loosly into the tin and its lower opening is large enough to allow the male spider to enter. The bottom of the tin is perforated with a few holes for the escape of water and any small lizards that may happen to fall into the trap. A female of the species is enclosed in a small glass jar fitted with a wire gauze lid and containing some moist sand or earth. The jar is then placed in the tin, the funnel inserted and the tin let into the ground until the top is level with the surface of the soil. A loose packing of leaf litter holds the tin in position and also allows any small lizards that have passed through the holes in the bottom of the tin to escape. In order to exclude rain a piece of old galvanised iron is placed over the trap and supported on two sticks leaving sufficient space for the spiders to enter the funnel.

The trap has proved most effective. Males attracted by the female pass down the funnel into the tin, from which it is difficult for them to escape. On one occasion when the trap had not been disturbed for five days eight males were found in it. All had spun flimsy silk coverings round the jar containing the female. Apparently no fighting between the males had occurred, since they were all in good condition and showed no signs of injury.

The use of the trap gives valuable information as to when the mating season begins and ends. Moreover, it helps in determining whether males and females belong to one and the same species.

ACKNOWLEDGMENTS

I wish to thank the Director of the Australian Museum for allowing me to examine co-types of *Atrax validus* Rainbow & Pulleine. My thanks are also due to Mr. N. L. Roberts for sending me a specimen of *Atrax formidabilis* Rainbow. I am indebted to Dr. G. Musgrave Parker and Dr. G. H. Kaire for articles from the Medical Journal of Australia dealing with the venom of spiders belonging to the genus *Atrax*.

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PLATE 1.
Atrax infensus sp. n.
(Photographs by P. Walker)

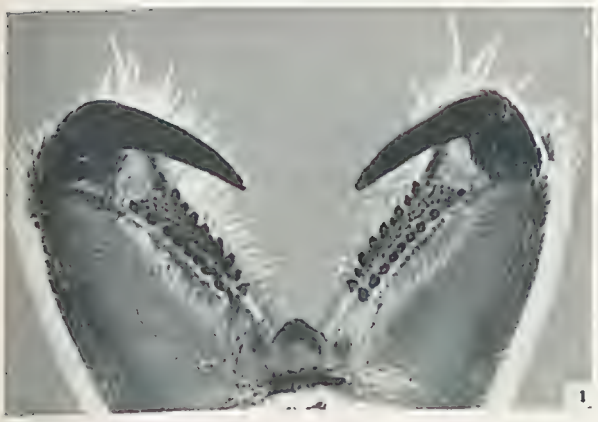

Fig. 1.—Chelicerae of female showing teeth.

Fig. 2.—Surface view of nest showing three funnel-like entrances leading to the burrow. Remains of beetles and millepedes may also be seen.

PLATE 2.
Atrax infensus sp. n.
(Photographs by P. Walker)

Fig. 3.—Male and female mating.

Fig. 4.—Female with egg-sac.

A SPECULATION OF THE RHAETO-LIASSIC CLIMATE OF TASMANIA

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ABSTRACT

It is suggested that the flora of the uppermost Triassic and basal Jurassic in Tasmania was a temperate one. This view is suggested by (i) the abundance of bryophytes, (ii) a paucity of vascular plant species, (iii) regular growth rings in petrified woods and (iv) the tendency for the Tasmanian representatives of a given species to be small. The conclusions agree, but not fully, with the conclusions reached from palaeomagnetic data.

INTRODUCTION

Deducing past climates from the fossil plants is difficult and uncertain, except where remains of living species or (sometimes) genera are available (Kräusel 1961, full discussion and literature). When the flora consists of extinct forms argument rests on anatomical features, now found in certain sorts of habitat (and this is not to say that they were always so restricted); and upon the general composition of the flora, using as far as possible the analogy from living plants. It is also unsafe to argue much from the distribution of species now plainly relicts, as *Ginkgo biloba* shows.

The Tasmanian Rhaeto-Liassic flora shows some unusual features and despite the uncertainties just mentioned, it is tempting to apply a climatic explanation, at least as a contributing factor. This explanation may in fact be the simplest. The suggestion is that the Rhaeto-Liassic flora was a temperate one, growing, it may be, in a climate not very different from today.

I am much indebted to Professor H. N. Barber, F.R.S., Mr. M. R. Banks, and Dr. R. Green for much useful criticism. To the managers (or owners) of the several collieries mentioned below I am grateful for permission to collect on their premises.

DISCUSSION

(1) *The limits of the argument.*

The argument is limited to the flora associated with the main coal seams, and of localities believed to be of more or less the same age. According to Hale (in Spry and Banks 1962) the main coal seams lie in the "Feldspathic Sandstone", itself lying at the top of the Triassic succession, e.g., in the Brady Formation of McKellar (pp. 226-229). This agrees with evidence from megaspores (below, and Hale *loc. cit*, pp. 224-226).

The plant fossils come from the localities listed on p. 15. Some of these have been dated as belonging to the zone of *Lepidopteris ottonis* (Upper Rhaetic) and of *Thaumatopteris schenki* (basal Liassic) by Dettman (1961). These are Langloh, the Cornwall mine in general and Barbers mine. Others, such as the Merrywood open cut, Dalmayne and the upper Douglas River, lie close to the dated localities, in the same suite of rocks and are almost certainly the same age. Yet others, however, e.g., Pateena and Forster Street, Hobart, lie at a distance from a dated locality and their date is not securely fixed. Some indeed (Prices Jetty, Mt. Christie mine) contain plants absent or very rare in the rest of the localities, and these localities may be slightly older than the others. Some which are almost certainly a good deal older (e.g., St. Virgils), or from which good material is no longer available (see Johnston 1888), are excluded altogether.

It is thus assumed that the flora discussed is mostly of Rhaeto-Liassic age, and any part not this age, only slightly older.

A limitation inherent in the evidence is that only that fraction of the flora that grew near where it is now fossilised is available. We knew nothing of the upland flora of Tasmania in the Triassic, and very little from anywhere else (Harris 1957).

(2) *Floras for comparison.*

The standard Rhaeto-Liassic flora is found in the sea cliffs at Scoresby Sound, East Greenland, and it is well known (Harris 1937, discussion and references). The fresh-water beds with plants overlie red beds (representing the final stages of the terrestrial phase of erosion following the Hercynian orogeny) on a level surface, and themselves were laid down by (probably) several rivers at or about sea level. The fresh-water sequence is followed by marine rocks. Contemporaneous floras, with similar histories and depositional conditions are found in Sweden (Troedsson 1938, Lundblad 1950, 1959), Germany (Gothan 1914, Jung 1960) and Poland (Racibroski 1894 for macrofossils), and the general history of the area is given by Gignoux (1950, especially pp. 214, 278-280, fig. 59). There are two main differences from Tasmania; the fresh-water sequence overlies desert beds, but in Greenland at least, there is evidence (Harris *loc. cit.* p. 101) that there was abundant water at the time the flora grew; and the fresh-water beds are over-

lain by marine, and this may not be important. In Greenland coal is present, but the seams are thin and impersistent; in Sweden, however, the seams are thick and workable. The parallel with Tasmania is not exact, but is close, and comparison would appear to be just.

The best known Mesozoic flora is that of the Bajocian and Bathonian in east Yorkshire (see Arkell 1933, pp. 313 *et sec.*, Harris 1952). This fresh-water sequence of deltaic origin, is both under- and overlain by marine beds. A longer time interval is covered, but there is little evidence of macrofloral change between the oldest and youngest plant beds. Comparison is made with this flora too, but there may have been differences in conditions of depostion.

It is difficult to obtain a southern flora for comparison. Three are possible, Ipswich (see Jones and de Jersey 1947), the Molteno (see Du Toit 1927) and the floras of the Argentinian Pre-Cordilleras (Frenguelli, e.g., 1943, 1947), but all present difficulties. There is no modern account of the Molteno flora, and the Molteno is probably mostly Middle Triassic (Watson in Townrow 1957). In the Argentine Frenguelli deliberately rejected microscopic data (1943 p. 227), which vitiates his identifications, and it seems clear that his floras range over a longer time than the Tasmanian ones. The Ipswich is perhaps the most useful, but here too Jones and de Jersey were hampered by lack of suitable material, and the Series covers a longer time than the Tasmanian Rhaeto-Liassic.

Admittedly, the Tasmanian flora needs revision, but this only makes it more important to compare with well-known floras. It also has the effect of rendering all conclusions tentative, but in the matters in which comparison is made below (especially numbers of species) the disparity between the floras compared is great.

(3) *Depositional environment.*

Hale (*loc. cit.* pp. 230-231) makes it clear that the Triassic in Tasmania is a fresh-water deposit, and it seems plain from the depositional structure, as from the existence of thick coal seams and a copious flora, that water was abundant. The only possible evidence to the contrary is deposits of gypsum along the bedding planes, seen locally lower in the succession. Tasmania at this time also formed a low-lying area, comparison is made with the Florida Everglades.

(4) *Characters of the flora.*

(*a*) The proportion of Bryophyles.

Eight species of liverworts and two mosses can so far be recognised in Tasmania, I supect there may be more, while the number of vascular plant species is, very tentatively, twenty-five to thirty. The Tasmanian figures are most unusual. The number of bryophytes is high both absolutely and in proportion. In Greenland there are four species of liverwort, but 160-180 of vascular plants. In the Yorkshire flora there are four (possibly six) liverworts known, but thirty ferns (Harris 1960) and some twenty-three conifers (Florin 1958), not counting other groups.

The only floras that compare are the Permain ones from the north of the U.S.S.R. (Neuburg 1960) in which there are ten or so species of mosses known. These floras, however, extend over most of the Permian, but the Tasmanian ones are contained in two zones only.

Most fossil bryophytes are rare, except the mosses just mentioned, and also *Naiadita*, which, however, grew in a rather special water habitat (Harris 1937); but in Tasmania, though they are only found in the finest grained deposits (a general feature of fossil bryophytes) they are not rare—there are thousands of specimens.

At the present bryophytes are commonest in cool moist climates or, in the tropics, on mountains (e.g., they are very abundant in the Himalayas). Since the Tasmanian environment was not mountainous, it would seem to follow that it was probably cool and moist. Neuburg (1960) uses a similar argument for her floras. It might be argued that the fossils have been carried from mountains to their present resting place, but the fact that delicate hairs and scales may be found rules this possibility out. Müller (1954) discussing liverwort distribution points out, however, that the Marchantiales and Jungermanniales Anacrogynae are less exacting than the Acrogynae, but it is to the Marchantiales and (probably) Jungermanniales Anacrogynae that the Tasmanian fossils belong.

(*b*) The number of species of vascular plants.

At a first and very provisional estimate the number of species of vascular plants can be allocated as follows:—

Marattiaceae—one species (usually given under *Taeniopteris*)
Osmundaceae—five species (the *Cladophlebis australis complex*)
Corystospermaceae—seven species (of leaf)
Ginkgoales—two species (one *Ginko*-like, one *Czekanowskia*-like)
Equisetales—one or two species (of *Equisetum*)
incertae sedis—*Phoenicopsis elongatus* (probably two species); *Linguifolium* and its allies (two species).

There are some notable absentees. No cycadophyte leaf is known from the flora discussed here, though *Pterophyllum* is known from lower in the succession. The only Triassic conifer known to me is a single shoot from a locality (Stonehenge) that may be older than any given here.

Fossil plants are not scarce, however. A good locality will bear comparison, for mere production of fossil matter, with some of the classic localities such as Cayton Bay. It is that only seven or eight species reward a week's search, instead of twenty or thirty. In fact, though not all the records are critical, this paucity of species appears in earlier accounts of the Triassic.

An impoverishment in species, but continuing abundance of individuals is characteristic of floras passing polewards: it is striking in Europe (Good 1947), and can be seen fairly well in some groups, such as ferns, today in Tasmania. It may be that the same phenomenon is seen in the Rhaeto-Liassic of Tasmania. There are two arguments

against this idea. The first is the absence of conifers. This is an important but not a conclusive argument. It is true that at the present conifers are mainly a temperate group but (i) the Order is now something of a relict, but it was not in the early Mesozoic, and (ii) though mainly temperate the numbers of species and genera do fall off towards the poles, so that the chief poleward extensions beyond Lat. 55° are composed of rather few genera and species (Florin 1963). The second argument is that there are no specifically temperate groups to be seen in the Tasmanian flora, though on the analogy from the present they would be expected; this may be no more than to say that the flora is as yet incompletely known.

The paucity of the Tasmanian flora is in marked contrast with the Northern Hemisphere floras (authors given above), and, so far as comparison is possible, it contrasts with the Ipswich, Molteno and the Argentine. A point to note, however, is that it also contrasts with the *Middle* Jurassic flora of Antarctica (Halle 1913).

In the case of the ferns direct comparison of fertile leaves is possible, as follows:—

Tasmania:
Marattiaceae—one species
Osmundaceae—five species (six)

Greenland:
Marattiaceae—two species
Osmundaceae—six species
Gleicheniaceae—one species
Dipteridaceae—seven species
Matoniaceae—three species (nineteen)

Yorkshire:
Marattiaceae—one species
Osmundaceae—five species
Dipteridaceae—
Dipterideae—one species
Camptopterideae—two species
Matoniaceae—five species
Schizeaceae—two species
Dicksoniaceae—
Dicksoniea—two species
Thyrsopterideae—eight species
? Aspideae—one species (twenty-seven).

The Greenland and Yorkshire floras are compared from an evolutionary point of view by Harris (1956). Lack of information on the fertile fronds makes comparison with other southern floras impossible.

At present both the Marattiaceae and Osmundaceae are relict Families, and little can be deduced from their present distributions. In the early Mesozoic, however, both were world-wide. The present day distributions are, Osmundaceae, temperate or tropical montane (Holttum 1950); Marattiaceae, tropical, but with extensions to New Zealand and Japan (Copeland 1947).

(*c*) Evidence from growth rings.

The classical indicator of a temperate climate is the presence of growth (annual) rings in the fossil woods available. Thus regular growth rings are seen in the petrified woods of Tasmania and southern lands in general during the Permian (e.g., Seward 1913, Seward and Walton 1923) when other evidence indicates a cool climate. There is little petrified wood available from the Tasmanian Rhaeto-Liassic, two coniferous-type trunks are present in the bed of the Douglas River above the third coal seam (going upstream) and I am indebted to Mr. M. R. Banks for telling me of others from Catamaran and South Cape Bay. This material is not well preserved and specifically indeterminable, but it does show prominent and regular growth rings, indeed, this is one of its most obvious features. In this it resembles, as noted, the Permian woods, and it is interesting that the rings look more regular than those of the Jurassic Rajmahal woods from India (Sahni 1931, Bhardwaj 1953, Suranarayana 1955).

The formation of growth rings is a most complicated matter (see Studhalter 1955, Glock 1955 for reviews and literature), for some plants (e.g., cycads) never seem to have formed growth rings, and growth rings can continue to be formed when the (supposed) conditions that lead to their initiation have vanished. Also causes such as a sudden access of light, as when an old tree falls, can lead to variation in growth ring pattern. It seems well established, however, that *regular* growth rings in *conifer type* woods are formed under cool moist conditions with a short growing season, the rings becoming less regular and more varied in nature going towards warmer dryer regions (Glock and Agerter 1963).

(*d*) The size of Tasmanian fossils.

Any comparison in size depends upon an accurate taxonomical treatment, which is scarcely possible yet. Among the Corystospermaceae, however, the leaf *Dicroidium odontopteroides* (taken to exclude *Thinnfeldia obtusiloba, T. acuta* and *T. supberba,* see Townrow 1957) is probably the leaf of one plant. From Umkomaas in the Molteno forty specimens had an average length of 7.5 cms., but thirty-five leaves from the old Mt. Christie mine han an average length of 5 cms. In the small populations available to me Tasmanian specimens of *Dicroidium feistmanteli,* and *"Reinitsia" spathulata* are smaller than specimens from elsewhere.

Leaf size also is a most complex matter involving an interplay between genetic and other factors in a given individual (see e.g., Stebbins 1950, pp. 40 *et seq.* for discussion and references). However, (i) within the same species populations showing small leaves (and a dwarf habit) tend to be found at higher latitudes and altitudes (Clausen, Keck and Hiesey 1948). Another point is that (ii) leaves produced when water is less plentiful tend to be small either on the same individual, or in different populations (e.g., Yapp, 1912, Salisbury 1927). Further (iii) many plants produce a succession of leaves of different sizes during the growing season. The small size of a leaf may be caused by its having fewer cells (as in high latitude populations), or smaller cells (as in "drought" leaves).

In the present connection the population as a whole is considered since it is impossible to say which plant produced which fossil leaf, and this tends to rule out consideration of the second and

third factors above. As noted, the evidence suggests that water was plentiful (though many bog plants today show xeromorphy). This leaves the effect of high latitude and high altitude. But the altitude was not high. The final possibility is therefore, that the latitude may have been.

(*e*) Abscission scars.

All the seed plants in which the leaf base is known show a structure looking much like, and interpreted as, an abscission scar (Townrow 1960 for discussion of appearance). This might mean that the leaves were deciduous, and the demonstration of an abscission scar is a necessary preliminary to showing that a fossil leaf was deciduous. On the other hand it might mean that the leaves were shed at intervals of several years, like the shoots (and needles) of many conifers. In any case, deciduous plants are not all temperate, neither are all temperate plants deciduous. On account of these considerations no argument is attempted on this point. Similarly, nothing is argued from the cuticular structure of the seed plants (actually it is rather varied in things such as sinking of the stomata), because until it is known whether the plants were deciduous or not no useful conclusion can be reached. Deciduous leaves only reflect conditions in the growing season.

I am unable to apply Dr. Plumstead's argument (1958). She points out that *Glossopteris* leaves occur in great abundance (leaf banks), but that the putative stems of these plants are rare, and from this deduces that the Glossopterideae were deciduous and probably temperate. They probably did grow in a temperate climate, but this evidence is not good enough. Almost any Mesozoic plant shows an apparent super-abundance of leaves, and the explanation almost certainly is that leaves and stems float differently, and so are found fossil in different places. Also an abscission scar has not been demonstrated yet for *Glossopteris* and its allies.

(5) *Consideration of other evidence.*

Paleomagnetic data (see Cox and Doell 1960, Irving, Robertson and Stott 1963 for summaries) suggests that throughout the Mesozoic Eastern Australia lay nearer the south geographic pole than it is today, and for the Middle Jurassic Tasmanian Dolerites (McDougall 1961, Evernden and Richards 1962), the pole is placed at (approximately) 51°S and 160°E: the present position of Hobart being, to the nearest degree, 43°S and 147°E. On the other hand the floras with which comparison is made are all further from the (then) pole, and in the case of the European ones, almost tropical (e.g., pole position Yorkshire, Jurassic, 85°N and 150°E). The exception is the Russian Permain, which may have been at a higher latitude (Cox and Doell 1960, p. 708), possibly warm temperate, and it is interesting that in respect of its bryophytes the Permian floras are somewhat comparable with the Tasmanian ones. At first sight agreement appears to be good.

On consideration difficulties arise. At present there is no flora at a comparable latitude South, at the same latitude North there may be a considerable one, but except for an area in north Russia, 70°N is beyond the limit of trees (Polunin 1959). But large trees occurred in the Tasmanian Rhaeto-Liassic. . Judging from the present (but see above p. 8) it is totally unexpected to find the Marattiaceae and Osmundaceae forming a considerable element in the flora.

The difficulty might be met by arguing that the present world climate, interglacial, is abnormally cool. In a non-glacial time (i.e., in absence of permanent polar ice) the world climate might be warmer, at least at high latitudes once the very great influence of the ice caps was withdrawn. The problem is discussed by Lamb (1961) who gives many references. A different distribution of land and sea around Tasmania would also affect climate.

Another argument might be that the extensive floras from both Arctic (Andrews 1961) and Antarctic (Plumstead 1962) indicate that plants could grow in these places, now impossible for most of them. If, however, it is once allowed that the position of the poles has not been constant, this argument is embarrassed by uncertainty whether the past latitudes of the polar regions are comparable with the present.

It seems to me that there is agreement between evidence from fossil plants and palaeomagnetic data only up to a point. Both agree that Tasmania in the Rhaeto-Liassic was not tropical, the plants a cool temperature climate, the palaeomagnetic evidence a latitude more consistent with an arctic climate.

CONCLUSIONS

The thesis that in the Rhaeto-Liassic Tasmania enjoyed a cool temperate climate has several lines of evidence to support it. However, it is not claimed that any is conclusive, and though they reinforce one another, the matter remains a suggestion. At best it might be taken as a useful working hypothesis.

It would perhaps be thought better to wait for more localities and species. I suspect this would be a wait in vain. Doubtless new species will be added, but a glance at the list on p. 5 shows that Triassic localities are not getting more numerous, and with the decline of the coal mining industry, are unlikely to do so.

Axelrod (1952) has suggested that the early Angiosperms evolved on the warm to tropical Permo-Triassic uplands. If so, it is unlikely, on the present arguments, that their remains will be found in Tasmania. Perhaps eastern Australia in general will not be the best place to look for them.

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APPENDIX

List of localities from which material has been utilised.

Derwent Valley—

Langloh coal mine:
- worked seam*
- upper seam*

Ouse River, cliff 3 miles N.W. of Ouse

Fingal Valley—

Cornwall coal mine†:
- loco section*
- main road (*a*)
- main road (*b*)

Jubilee open cut:
- lower seam, floor*
- upper seam, roof
- shales*

Jubilee mine, dump*
Barbers mine†:
old tunnel*
new tunnel
Duncan mine, dirt band near roof*
Yeats mine, chitter from dump*
Merrywood open cut:
roof shales
shales 20-30 ft. above seam
Old Mt. Christie Mine:
black shale
in seam*
Stanhope mine, dirt band*

East Coast—

Douglas River:
lower seam*
top seam. dirt partings
Dalmayne mine, dirt partings
Creek (un-named) near Gray P.O., creek bed*

Tasman Peninsula—

Prices Jetty, shales on foreshore

North—

Pateena mine, dump

Hobart—

Forster Street brick pit*

NOTE.—The above list is not exhaustive, but includes a high proportion of the localities yielding *good* fossil plants.
* Denotes that the locality is extinct.
† Considered as separate localities, though on the same general horizon, because the localities are separated by several hundreds of yards of (somtimes) barren shale. The plant-bearing shales lie in a band up to 16 ft. thick above the worked seam, and it is likely that not all material comes from the same level within this shale band.

THE GEOLOGY OF THE COLLINSVALE AREA

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(With five text figures and two maps)

ABSTRACT

A cone sheet of Lower to Middle Jurassic dolerite intruded into sub-horizontal Permian and Triassic strata is the dominant geological feature in the Collinsvale area. Within the throat of the cone sheet there was extensive faulting concomitant with the intrusion. The course of intrusion and the pattern of the faulting were controlled by the pre-intrusion structure. The cone sheet is a major centre of intrusion and is joined on its flanks by further dolerite intrusions.

The rocks of the area are complexly broken by tensional faulting associated with Tertiary epeirogeny, and the faulting is markedly influenced by the Jurassic structure. The rocks are strongly jointed.

Almost the whole of the Permian and Triassic sequences are exposed within the area. The Permian System contains both marine and fresh-water deposits, and is exposed to a stratigraphic level low down in the Woody Island Siltstone. Mudstone, limestone, sandstone, and sub-greywacke type rocks form a succession 2,000 feet thick. The Triassic sequence of fresh-water sandstone and shale totals about 1,200 feet in thickness, and overlies the Permian System possibly with a slight unconformity.

Remnants of Tertiary basalts are present.

INTRODUCTION

The Collinsvale Square is the ten-kilo yard square 5072, bounded on the west and east by the grid lines 500000 yds. E. and 510000yds. E. respectively, and on the north and south by the grid lines 730000 yds. N. and 720000 yds. N. respectively.

Mapping was accomplished by recording the field data on aerial photographs. The base map was made by transferring the data onto a grid of 4 inches to the mile, by means of a rectiplanigraph. The grid was constructed by the slotted-template method and the lay down controlled horizontally by 6 trigonometrical stations.

Grid references are given as 6 figure coördinates referred to the State grid system. Specimen numbers are those of specimens catalogued in the Geology Department, University of Tasmania.

PREVIOUS LITERATURE

Comparatively little previous work has been carried out on the geology of the area. Voisey (1938) investigated the Permian rocks along the Collinsvale and Glen Lusk Roads, and Lewis (1946) mapped and briefly described the eastern margin of the area. (Banks 1957, 1958), and Banks and Hale (1957), mentioned some of the Permian outcrops. Hughes (1957), Brill (1956), and Hale and Brill (1955) have described the limestone deposit at the Berriedale Quarry.

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PHYSIOGRAPHY

The topography of the area is rugged and its development has been controlled by the nature of the rocks and the geological structure.

The dolerite has profoundly influenced the topography mainly through the resistance of this rock to erosion. The central cone sheet has been extensively exhumed and is expressed topographically by the Collinsvale basin and the valley of Faulkners Rivulet. All the high parts in the area consist of or are capped by dolerite. Scree and talus deposits skirt the dolerite highlands, and west of Collins Bonnet aprons of dolerite talus spread by periglacial action blanket much of the country.

Faulting has also been important in the topographical development and has exercised a strong influence on the drainage pattern. Many of the streams have cut their courses, in part, along fault lines. The main streams are tributaries of the Derwent River and the present drainage was initiated by Tertiary epeirogenic faulting. The spectacular gorges of the Sorell River and Mount Rivulet, the incised meanders of the Sorell River at Collinsvale, and the steep valleys of Humphrey Rivulet, Knights Creek, &c., have all been cut into the uplifted country bounding the Derwent Graben and the Dromedary Horst (Banks, 1962 *b*). The course of the Sorell River suggests river capture. Faulkners Rivulet, which is a misfit stream, probably marks the old course and the capture took place when the Sorell River cutting back into the Sorell River Fault scarp breached the dolerite wall of the cone sheet.

PERMIAN SYSTEM

The rocks of the Permian System exposed in the area are 2,000 feet thick and include both marine and fresh-water deposits. Some of the

poorly sorted marine beds are probably turbidity current deposits (Banks, 1962 *a*) while the presence of faceted pebbles in parts of the sequence indicates glacial contribution. The fresh-water beds near a cyclothemic relationship to the marine beds.

Parts of the sequence show well developed rhythmic bedding, caused by alternations of massive and fissile units, and richly fossiliferous horizons are present. The sequence is Sakmarian to Kungurian in age (Banks, Hale, and Yaxley, 1955, Banks and Hale, 1957) and consists of 18 formations, summarised below with their average thickness.

	? Cygnet Coal Measures	?
Kazanian and Kungurian	Ferntree Mudstone	600 feet
	Risdon Sandstone	15
	Malbina Sandstone and Siltstone	280
Artinskian Cascades Group	Grange Mudstone	60
	Berriedale Limestone	140
	Nassau Siltstone	60
	Rayner Sandstone	10
Faulkner Group	Fergusson Siltstone	35
	Altamont Conglomerate	1
	Parramore Sandstone and Siltstone	10
	Jarvis Siltstone	25
	Byers Sandstone	3
	Rathbone Sandstone and Siltstone	20
	Geiss Conglomerate	1
	Bundella Mudstone	140
	Darlington Limestone	100
Sakmarian	Satellite Siltstone	40
	Woody Island Siltstone	?450
		2,000 feet

The formation of the Faulkner Group proved difficult to map separately in the field, and the Group as a whole was used as the mapping unit.

WOODY ISLAND SILTSTONE

These are the lowest Permian beds exposed in the Hobart area and consist of at least 380 feet of siltstone. Measurements made along the creek beds west of Mary's Hope Road indicate that the thickness is probably greater than 450 feet.

The siltstones when fresh are blue-grey to greyish black and weather to dark yellowish brown or light grey. Bedding is thick. An irregular fissility is conspicuous but the true bedding is difficult to discern. Outcrop is very poor and the best exposures are seen in the road cuttings of the Collinsvale and Glen Lusk Roads.

The fresh siltstone is pyritic, and the pyrite is replaced by limonite on weathering. Cavities of a shape suggestive of glendonites were observed on some weathered surfaces. Peebles are rare, being mainly rounded to angular quartzite pebbles less than three inches in size. Limonitic siltstone concretions occur and are commonly one to three inches across. They have a central cavity filled with limonite and clay, and some are lined with quartz crystals. Twinned concretions are seen inclined to the bedding, and are due to the coalescence of two concretions on different levels.

A typical siltstone, peppered with small brown spots, in thin section 30169 consists of angular quartz grains, and clay. The quartz grains form 30% of the rock and no grains larger than 0.15 mm. were seen, the majority being 0.05 mm. The clay forms 50% of the rock and most of the remainder is limonite distributed in blebs and blotches. Other minerals present include feldspar, zircon and rutile grains.

Fossils are uncommon but small ? clam shells, part of a *Gangamopteris* leaf, a few fenestellids, a small *Eurydesma cordatum* and some small spiriferids were found.

Where the siltstones are intruded by dolerite, they have been metamorphosed and silicified along the contact to bluish and dark grey quartzite containing grains of pyrite.

The poor bedding, fine grain size and good sorting suggest that the Woody Island Siltstone was deposited continuously in quiet conditions with occasional deposition of peebles possibly from ice rafts. The pryitic content and paucity of fossils indicate that the environment was reducing and rather inhospitable to life.

SATELLITE SILTSTONE

Approximately 40 feet of fossiliferous siltstone overlie the Woody Island Siltstone, and these beds have been correlated with the Satellite Siltstone (Banks, Hale and Yaxley, 1955). Exposures of the formation are very poor.

Medium dark grey siltstones, which weather yellow-brown, are poorly exposed in the creek at 1,014E-2,811N. The rocks show bedding from one to five feet thick, and irregular fissility. Bryozoa are especially abundant and include *Fenestella, Polypora* and *Stenopora. Grantonia,* other spiriferids, ? strophalosians, and pecten shells are also common. *Stenopora* ? *tasmaniensis* and *Peruvispira* were noted from a small outcrop, cut off on both sides by faults, at 857E-834N on the Glen Lusk Road.

DARLINGTON LIMESTONE

Fossiliferous limestones, calcareous siltstones, and siltstones overlie the Satellite Siltstone and have been mapped as the Darlington Limestone. The thickness was measured as 150 feet in the creek at 1,012E-2,809N, 120 feet on the Glen Lusk Road, and between 80 and 100 feet on the southern hillslopes of Mt. Faulkner. The first two values seem excessive and may be due to faulting. The only well exposed section is the outcrop along the Glen Lusk Road.

The basal part of the formation consists of alternations of bryozoal siltstones and calcareous brachiopod siltstone, and is exposed along the branch off the Glen Lusk Road. The bryozoal siltstones are one to four feet thick and contain stenoporids—a few in living position—*Strophalosia,* ? *Merismopteria,* and pecten shells. The brachiopod units are one to two feet thick and contain spiriferids, strophalosians, aviculopectinids, stenoporids, and gastropods. They vary from

siltstones containing limestone lenses to poorly sorted silty limestones with arenaceous shell fillings.

This alternation is interrupted some fifteen feet above the base, and the succession continues with calcareous siltstone, some siltstone, and brachiopod limestone. The calcareous siltstones are hard, bluish grey and show slightly irregular bedding. The rock appears well to moderately well sorted in the hand specimen and contains sporadic angular to rounded pebbles. Thin section 30155 of a calcareous siltstone shows 35% angular quartz fragments ranging in size up to 0.8 mm. with prehnitisation of the calcareous matrix. Some units are bryozoal, containing dominantly stenoporids, others are sparsely fossiliferous. The siltstone beds are crumbly yellowish brown, irregularly bedded and are massive to fissile, the fissile parts being rich in fenestellids. The brachiopod limestones vary from moderately well sorted units containing sporadic angular to rounded pebbles to poorly sorted units containing much arenitic material and fragmentary and haphazardly orientated shells.

Eurydesma-calcirudites are prominent in the higher parts of the sequence. On the Glen Lusk Road they first appear 80 feet above the base, and the top 15 to 20 feet consists of alternating *Eurydesma*-calcirudites and spiriferid-calcirudites. These beds are massive, two or three feet thick, and foetid when struck with the hammer. Rock fragments are present as rounded to angular pebbles. In the *Eurydesma* units the shells are convex and concave upwards, and are associated with large pectinids, *Grantonia,* strophalosians, fenestellids and stenoporids in a silty matrix. The spiriferid units include *Grantonia,* stenoporids, and ? *Keenia. Calcitornella* occurs in these top beds (Banks 1957, p. 60).

Calc-silicate hornfels have formed along intrusive dolerite contacts. A light greenish grey hornfels collected at 821E-826N in thin section 30156 is a fine grained aggregate of calcite (40%), ? wollastonite (35%), chlorite (10%) and diopside, grossularite, vesuvianite, and sphene. Another hornfels, yellow-green in colour, from 849E-873N in thin section 30157 shows concentrations of diopside crystals (less than 0.3 mm.) on the borders of stenoporid fossils composed of recrystallised calcite. The matrix contains 30% quartz fragments less than 0.3 mm. in size with incipient development of diopside and ? prehnite.

BUNDELLA MUDSTONE

Outcrops of this formation are poor and no complete section is exposed. The thickness of the formation is between 110 and 150 feet.

Yellow-brown siltstones, some of them rich in fenestellids and stenoporids immediately overlie the Darlington Limestone on the Glen Lusk Road, but the succession is disrupted by faulting.

Poorly sorted olive-grey siltstones of this formation outcrop along the Collinsvale Road below the limestone quarry. The bedding is up to two feet thick and consists of alternations of massive and fissile units. The more fissile units are particularly rich in fenestellids. The fauna of the beds includes *Stenopora ? tasmaniensis, S. johnstoni, Fenestella, Polypora, Ingelarella, Grantonia, Streptorhynchus, Strophalosia* (new species), *Keeneia trochiforme, Peruvispira* (with double band), *Eurydesma cordatum, E. ? hobartense, Dielasma, Stutchburia, Aviculopecten ? elongatus, Camptocrinus,* and ostracodes.

The top beds of the formation are relatively unfossiliferous but in places contain small bryozoans, small spiriferids, and ostracodes. Dusky yellow siltstones comprising the top nine feet of the formation are well exposed at 814E-766N. These beds are alternations of fissile and non-fissile units, the latter showing slightly irregular bases. The fissile units tend to be the thicker reaching over two feet in thickness. The sorting is poor and the pebbles generally less than three inches across. A conglomeratic siltstone is a consistent horizon near the top of the formation and in this section the eighth unit from the top is a massive, four-inch thick, pebbly, coarse siltstone.

"Fontainebleu" siltstone lenses were noted in the formation at 1,004E-2,787N.

FAULKNER GROUP

All the formations named in the type section of the Faulkner Group at Mt. Nassau (Banks and Hale, 1957) have been recognised in the mapped area. The Group represents two cyclothems and is about 90 feet thick.

Geiss Conglomerate.—This formation is exposed at 1,002E-2,773N, and on the Glen Lusk Road at 814E-766N. At the latter locality it overlies the Bundella Mudstone with an irregular basal contact marked by layers, nodules, and concretions of limonite. This limonite layer encloses clay pellets, pebbles and poorly preserved stem-like remains, and possibly represents an old erosion surface.

The conglomerate is up to seven inches thick but is not everywhere continuous. It is olive-brown in colour when fresh and is poorly sorted, consisting of numerous pebbles set in a coarse arenaceous matrix of angular quartz, feldspar and mica fragments with a ferruginous cement. The pebbles are up to four inches in size and many are quite angular, although the majority show some degree of rounding. Pieces of silicified wood are present.

Rathbones Sandstone and Siltstone.—This formation is 15 to 20 feet thick. Excellent exposure occurs on the Glen Lusk Road at 814E-766N.

A yellow-grey to yellow-brown sandstone, a few inches thick, overlies the Geiss Conglomerate at this locality. Thin lenses of carbonaceous to siliceous siltstone intervene between the two in places. The sandstone is a poorly sorted coarse to medium grained arenite, rich in feldspar, and contains a few rounded pebbles and fragments of silicified wood. A two-inch thick lens-like body of siliceous siltstone follows, then a three to five-inch thick fine grained, friable, argillaceous and micaceous sandstone.

The friable sandstone member is overlain by seven feet of well-sorted yellowish grey quartzose sandstones, and light olive-grey, fissile and mica-

ceous coarse siltstones. The bedding is variable in thickness and lensing is common. The last five feet become more thinly bedded. Large and small scale current bedding is present and the massive quartzose sandstones show ripple marking with wave lengths up to six inches long. A few poorly preserved plant remains were observed on bedding planes.

The top of the formation consists of eight feet of thinly layered carbonaceous and micaceous fine siltstones. The siltstones are olive-grey weathering to light grey or dun, and form beds two to three inches thick. Small lenses of fine arenitic material are present, and worm castings and tracks were noted on the bedding planes.

A possible paleogeographical reconstruction of the depositional environment is shown in Fig. 1. The environment ranges from marine, represented by the Bundella Mudstone, to fresh-water lacustrine, represented by the well sorted sandstones and siltstones of the Rathbones Formation. The retreating sea was fringed by pockets of pebble beaches forming the Geiss Conglomerate. Behind and between the pebble beaches were sandier beaches forming the first unsorted sandstone member. Fresh-water lakes occupied the land behind the beaches, and marginal reworking on the lake shore formed the friable sandstone member. The beach was littered with pieces of driftwood and there were also shallow pools that filled with silt. The unsorted nature of the beach material indicates a rapid retreat of the sea.

Byers Sandstone.—The formation is only exposed at 814E-766N where it overlies the Rathbones Formation with a markedly irregular basal erosional surface. It is two feet nine inches thick and is a yellowish brown, poorly sorted, pebbly sandstone. The pebbles are mostly rounded, an inch or less in size, and are concentrated toward the base and top. Thin section 30159 shows the rock to consist of angular quartz grains up to 5 mm. in size (40%), small rock fragments of quartzite, slate and mudstone (30%), feldspar grains (5%), a few mica flakes and grains of ilmenite, and a chloritic and argillaceous matrix. The fragments of mudstone were possibly derived from shallow water scouring of the underlying Rathbones Formation in a marine advance.

Jarvis Siltstone.—This formation is very similar in lithology to the top beds of the Bundella Mudstone, but no fossils were observed. It is 25 feet thick at 1,002E-2,771N. Here it is overlain by an 18-inch thick poorly sorted pebbly siltstone in which a dropped pebble was noted. The basal two or three inches are conglomeratic and also contain lenses of coarse unsorted sandstone. This unit was not reported in the type section at Mt. Nassau, and fully completes the double cyclothem.

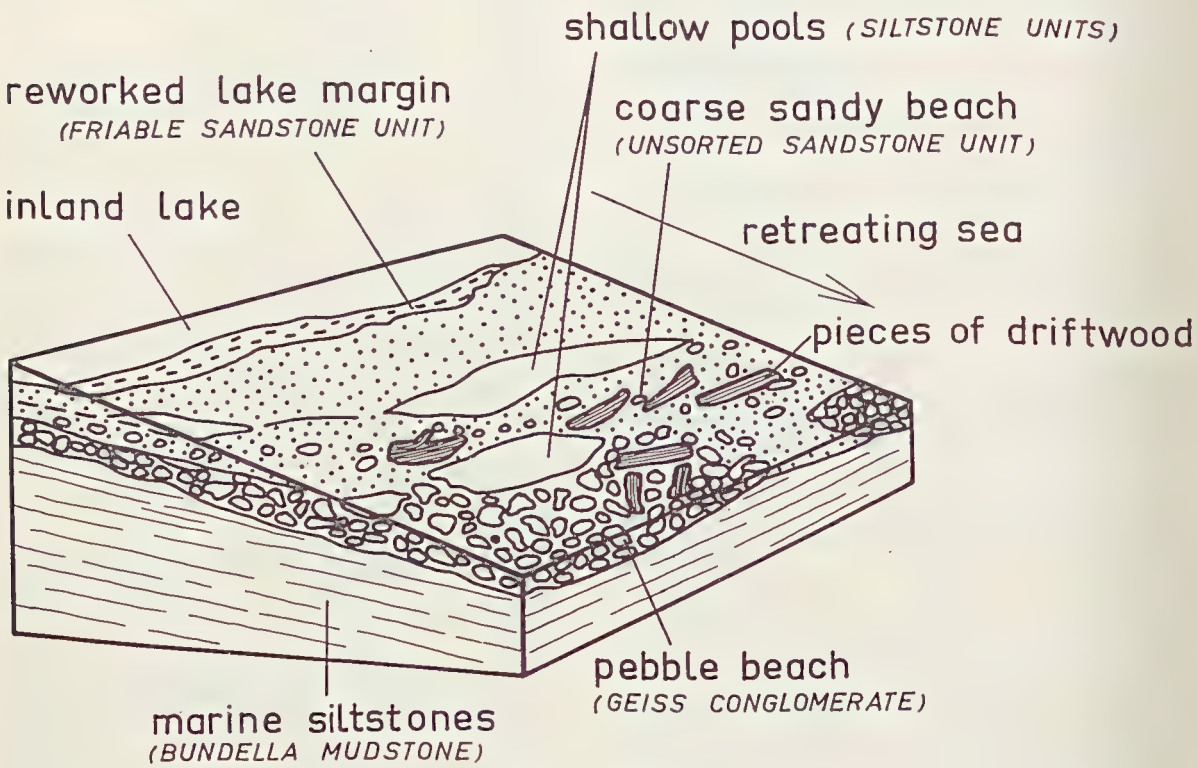

FIG. 1.—Paleogeographical reconstruction of the littoral zone in the Glen Lusk area during the retreat of the Permian sea in Artinskian time.

Parramore Sandstone and Siltstone.—These fresh-water beds are 10 feet thick and consist of thinly bedded, fissile carbonaceous and micaceous siltstones, with some thin beds of quartzose sandstone toward the top.

Altamont Conglomerate.—This formation is exposed at 1,002-E2,771N. A hard conglomeratic arenite, five inches thick, it is lithologically similar to the Byers Sandstone.

Fergusson Siltstone.—The formation is between 30 and 40 feet thick. The bottom 10 feet consist of alternations of fissile and non-fissile, poorly sorted, dark grey siltstones that weather light-grey or dun. Conglomerate and breccia units similar to those described in the type section are present. The top part of the formation consists of dark grey, mainly fissile siltstones, in which a few small spiriferids were found.

RAYNER SANDSTONE

Good outcrops of this formation occur on the Collinsvale Road both below and above the limestone quarry, at 716E-564N, at 744E-785N, and at 800E-891N. It is five to ten feet thick and consists of pebbly, olive-grey feldspathic sandstone and coarse siltstone. The bedding is massive and thick and the rock is poorly sorted, containing angular to rounded pebbles. In places is similar to the outcrop in the type section at Mt. Nassau, consisting of a relatively unfossiliferous lower unit, a friable central unit, and a fossiliferous top unit. Spiriferids are the main fossils present and include *Ingelarella* and a species with a long hinge line. Fragments of fossil wood and plant stems occur.

A specimen from 856E-816N in thin section 30160 consisted of 40% angular to rounded quartz grains mostly between 0.6 to 1mm. in size in a matrix of fine silt. Angular to sub-rounded fragments of quartzite and quartz up to 8 mm. in size formed 20% of the rock.

CASCADES GROUP

All three formations of the Cascades Group outcrop in the area. The boundaries between the formations are gradational. The thickness of the Group is between 250 feet and 300 feet. The Nassau Siltstone is relatively constant in thickness but considerable facies variation exists between the Berriedale Limestone and the Grange Mudstone.

NASSAU SILTSTONE

This formation is 50 to 60 feet thick and consists of massive and fissile siltstone. It is well exposed on the Collinsvale Road above the crossing of the Tarraleah power line.

The fresh siltstone is grey-black, but weathers medium grey to dun. The bedding is thick, and tends to be obscured by the fissility. The rock is poorly sorted, containing numerous angular quartz grains and pebbles are sparse. Limestone lenses occur and a limestone bed, about one foot thick, is a consistent horizon a couple of feet above the base.

The formation is richly fossiliferous, although the basal beds are rather barren in places, as at 700E-740N and west of Glen Lusk. The fauna is dominated by laminar and ramose stenoporids, fenestellids including both fan-like and frond-like colonies, and strophalosians in many cases as overturned shells. *Ingelarella,* other spiriferids, *Aviculopecten sprenti,* and crinoidal plates were also noted.

BERRIEDALE LIMESTONE

The thickness of the formation is between 130 and 150 feet around Collinsvale and Glen Lusk. Brill (1956) recorded the thirty-foot section exposed in the Berriedale limestone quarry and made correlations with other sections in the Hobart area.

The formation consists of alternations of massive limestone and fissile siltstone. The limestones are thickly bedded, being two to three feet thick, contain an appreciable amount of clastic material, and are best termed calc-arenites and calcilutites. The siltstones are more thinly bedded than the limestones and may be only a few inches thick. The limestone beds show pinch and swell with wave lengths up to 10 feet. Banks and Hale (1957) consider this to be ripple-marking.

Erratics, up to a foot across, are common. Many of them are angular and faceted, but smoothly rounded pebbles are also present. Dropped pebbles can be proved (Banks and Read, 1962). The erratics tend to be concentrated in the siltstones or in the tops and bottoms of the limestone beds (Brill, 1956) and were presumably dropped from ice rafts. Banks and Hale (1957) consider that this supports the view that the siltstones represent periods of glacial advance while the limestones represent periods of glacial retreat.

The clastic content of the limestones increases in the higher beds. Thin section 30161 of a massive limestone from near the top of the formation at 827E-762N shows lenses, patches, and stringers of coarse silt to sand grade material in a very fine grained silt base. The coarser material forms about 35% of the slide, and consists mainly of sharply angular fragments of high to low sphericity, composed of quartz, feldspar, chert, slate, phyllite, and mudstone. The calcareous content appears to be quite low.

A feature of the Berriedale Limestone is "tan, waxy looking shale" beds noted by Hale and Brill (1955) and regarded by them as the product of distant volcanic outbursts. Three horizons of bentonites are visible in the Berriedale limestone quarry. The lowest is overlain by a fissile siltstone with a slightly irregular boundary, but the next band lies between two limestone units. This observed lack of regularity in deposition favours the volcanic hypothesis of Hale and Brill.

The formation contains a rich and diversified fossil fauna (Voisey, 1938; Banks and Hale, 1957; Banks, 1957).

The limestones show extensive prehnitisation along intrusive dolerite contacts. A green hornfels collected at 497E-682N in thin section 30162 consisted of 70% prehnite.

GRANGE MUDSTONE

The Grange Mudstone is between 40 and 70 feet thick around Collinsvale and Glen Lusk, but becomes considerably thicker to the south-east, and at the top of Tolosa St. is 140 to 160 feet thick. The Berriedale Limestone is not exposed at this latter locality but its thickness probably decreases correspondingly, as in Weiley's Quarry, about half a mile away, it measures less than 100 feet.

The mudstones of this formation are greyish black but weather cream and light brown, weathering easily to give poor outcrops. Most beds are less than nine inches thick. The mudstone appears to be better sorted than the siltstone of the Berriedale Limestone and erratics are less common. There is a persitent limestone bed, one foot thick, just below the top of the formation, and an 18-inch thick strophalosian limestone was observed 60 feet below the top at Tolosa St.

An abundance of fenestellids and stenoporids gives the upper beds a strong lamination. The fauna includes *Fenestella,* very fine ramose stenoporids (*Stenopora* ? *grantonensis*), *Polypora, Strophalosia* ? *typica, Spiriferellina, Ingelarella, Aviculopecten sprenti,* small coiled gastropods (? *Warthia*) and *Gangamopteris.*

MALBINA SANDSTONE AND SILTSTONE

The succession in this formation is similar to that in the type section (Banks and Read, 1962) but good sections are lacking. .

Cream to yellow-brown sandstones and pebbly sandstones belonging to the lower part of Member A are exposed on the Collinsvale Road above the limestone quarry. They overlie the Grange Mudstone but the contact is not clearly seen. The pebbly sandstones are poorly sorted and the pebbles are mostly angular with high to low sphericity. Large spiriferids, including *Ingelarella, Strophalosia,* large gastropods and rare small stenoporids are present. The better sorted finer sandstones contain fenestellids.

Massive poorly sorted sandstones and coarse siltstones interbedded with thinner fissile siltstones outcrop at 584E-578N and probably belong to the lower part of Member A. The massive units are up to a foot thick, show slightly irregular bases, and contain mostly angular, but some highly rounded, pebbles. Some of the massive units contain lenses of richly fossiliferous bryozoal siltstone, otherwise fossils are uncommon and mainly spiriferids. The fissile units are richly fossiliferous in patches containing bryozoans, spiriferids, and gastropods.

The dusky yellow-brown sandstones with subordinate siltstones that outcrop at 830E-700N may belong to the top part of Member A. The sandstone beds are medium to fine grained, massive and about a foot thick. They are poorly sorted being composed of angular grains of quartz, feldspar, zircon and even biotite. They contain flat thin pebbles of slate and phyllite and rare moulds of spiriferids including *Ingelarella.* Pieces of silicified wood were noted in a 15-inch thick breccia-sandstone. The siltstone beds show slump structure and are unfossiliferous.

Members B and D proved difficult to identify separately in the field as they both contain similar fissile siltstones which weather easily to give poor outcrops. Beds of this nature outcrop along the Collins Cap Road past Collinsvale, and on the Tarraleah power line above 838E-703N. Fossils and pebbles are very rare in these beds.

A conglomeratic pebbly sandstone outcrops on the Tarraleah power line above 838E-703N, and was mapped as Risdon Sandstone. However dolerite scree cover prevented definite identification and this may be Member C.

Member E is well exposed in Humphrey Rivulet, above the top end of Tolosa St., and at 080E-640N. This member is 20 to 30 feet thick and consists of cream to light brown siltstones and sandstones. These beds are generally well sorted and pebbles are rare. The top 10 feet contain a profusion of *Strophalosia ? ovalis* and *Terrakea,* associated with fenestellids, stenoporids, and small gastropods. Limestone lenses are common toward the top and in Humphrey Rivulet the final five feet is a foetid, bluish-black, pyritic, silty limestone, containing spiriferids, including *Ingelarella,* and strophalosians.

The depositional environment of the Malbina Formation has been discussed by Banks and Read (1962). They attribute the pebbly, poorly sorted coarser beds to turbidity current deposition rather than glacial deposition.

RISDON SANDSTONE

The formation is 10 to 15 feet thick and outcrops prominently in many localities. It is well exposed on the north-east ridge of Mt. Wellington and at 808E-640N.

It is a thickly bedded, yellow-grey, pebbly arenite, composed of angular to sub-rounded grains of quartz and feldspar. Breccia and conglomerate bands are present, particularly in the basal part of the formation. Many of the rock fragments present are very angular with low sphericity, but some are highly rounded. The fragments are up to five inches across and are dominantly of vein quartz and quartzite.

A few poorly preserved spiriferid moulds, and, in some places, numerous pieces of fossil wood were noted in the coarser bands.

FERNTREE MUDSTONE

The thickness of the formation is about 600 feet. No suitable section was found for detailed measurement, but it appears to correspond more closely with that in the Sandfly-Oyster Cove area (Rodger, 1957) than with that in the adjacent New Norfolk area (Woolley, 1959).

The lower part of the formation consists of thick bedded, hard, grey siltstone, 150 to 200 feet thick, which outcrops in many places as steep cliffs. The bedding is one to three feet thick. Some of the beds tend to be fissile toward the top, and thinner beds of fissile siltstone are also present. The siltstones are poorly sorted, consisting of numerous angular quartz fragments in a very fine grained clay matrix, and contain small pebbles.

A horizon of dark yellow-brown, thickly bedded, pebbly sandstone, eight feet thick, outcrops at 855E-695N and is overlaid and underlain by greyish siltstone. These beds are referred to the Ferntree Mudstone and if so then the pebbly sandstone horizon occurs at about 50 feet above the base. The rock is composed dominantly of angular quartz grains and the rock fragments are up to a foot across and very angular. It is very similar to Member "B" described by Woolley (1959).

The lower part of the formation is followed by approximately 200 feet of yellowish, slightly friable, poorly sorted silty sandstone containing rare pebbles.

The top part of the formation consists of poorly sorted greyish siltstones and sandstones. Variations in the coarseness of the constituent material give the rocks a mottled appearance on weathering. Slump structure is common and small scale current bedding was observed. Worm casts on bedding planes and worm tubes at a high angle to the bedding are common. Conglomeratic horizons are present. A poorly sorted, yellowish coarse conglomeratic sandstone outcrops on the north-east ridge of Mt. Wellington, about 450 feet above the base. Poorly preserved spiriferid moulds were found at 567E-180N and on the north-east ridge of Mt. Wellington about 470 feet above the base of the formation. Numerous pieces of lignified wood occur in lenses of conglomeratic siltstone close to the top of the formation at 442E-960N.

The Ferntree Mudstone appears to be a thick deposit of estuarine muds and sands deposited in fairly shallow water. The incursion of coarser material carried in by turbidity currents from time to time is suggested by the conglomeratic and breccia horizons.

CYGNET COAL MEASURES

No outcrop of these beds was found in the area. The formation may be present, but not exposed. Some 30 feet of these beds outcrop in New Town Creek just to the south-east of the area (Lewis 1946, p. 95).

TRIASSIC SYSTEM

The Triassic System is a sequence of lacustrine sandstones, siltstones and subordinate conglomerates. It overlies the Permian System with an erosional break, the nature of which is considered more fully later. The following formations have been mapped:—

"Feldspathic Sandstone"	200 + feet
Knocklofty Sandstone and Shale	600
Springs Sandstone	400
Total Stratigraphic Thickness ..	1200 + feet

SPRINGS SANDSTONE

Massive sandstones dominate the formation and outcrop prominently, in places, as steep cliffs. The thickness of the formation is between 380 and 400 feet.

The base of the formation is nowhere exposed. The basal beds are conglomeratic, as at 029E-451N where a seven foot thick bed of poorly sorted conglomeratic coarse sandstone overlies coarse sandstone with an uneven contact. The pebbles in the conglomeratic beds are dominantly sub-angular to sub-rounded siliceous fragments up to three inches across.

Thick bedded coarse sandstones are particularly common in the lower part of the formation and vary from dirty unsorted types to clean sparkling quartz sandstones. Pebbles are present, scattered both sporadically and in stringers marking the tops of beds. Thinly bedded well sorted sandstones become more common toward the top of the formation. The only fossils seen were fragmentary pieces of wood.

An interesting white sandstone mottled by brown bands was collected at 478E-918N, 100 feet above the base of the formation. In thin section 30164 this is a feldspathic sandstone composed of angular grains of quartz (55%) microcline and microperthite (25%), and bands of triangular, rectangular, and rounded garnet grains. The average grain size is between 0.8 mm. and 1 mm. Shreds of mica are twisted around some of the fragments, and zircon and tourmaline grains are also present. The garnet grains are cemented with limonite giving the rock its brown banding.

Large scale current bedding, scour and slump structures are a feature of the sandstones. The current bedding is festoon in type and overfolding along the margins, attributed to current drag (Read, 1960), is common.

Siltstones and mud pellet conglomerates occur but are comparatively rare and thin. A three-foot thickness of carbonaceous siltstone was observed in the basal beds at 029E-451N.

KNOCKLOFTY SANDSTONE AND SHALES

This formation contains a greater proportion of shaley siltstone than the Springs Sandstone. The siltstones are susceptible to weathering and rarely outcrop. The base of the formation is marked in places by a distinct bench cut in along a siltstone horizon. Beds of greenish siltstone, up to four feet thick are exposed in the Mount Rivulet at 000E-349N. They are massive to shaley, well sorted, and commonly micaceous.

Massive coarse to medium grained sandstones are common, but there is a preponderance of thinly bedded, almost shaley, fine sandstones. The sandstones are yellow to white in colour and are well sorted. The massive coarser sandstones are composed almost entirely of sub-angular to rounded quartz fragments with minor amounts of feldspar and mica, and little matrix. They contain clay pellets, ferruginous nodules and sporadic pebbles. The finer sandstones contain appreciable amounts of muscovite and graphite on the bedding planes. Large scale current bedding, scour and slump structure are a feature of the sandstones just as in the Springs Sandstone. Measurements of current bedding directions made in both formations indicated that the currents came from the north-west, west, and south-west.

Mud pellet conglomerates are present and are more abundant toward the top of the formation. They are lens-like bodies, mostly between one and three inches thick, but reach up to seven inches. They are composed of numerous clay pellets and in same cases pebbles, set in an arenaceous matrix. The clay pellets are ellipsoidal, commonly show alignment parallel to the bedding, and are up to three inches long. They were most probably derived from drying clay beds.

"FELDSPATHIC SANDSTONE"

Exposure of the formation is poor. Some outcrops occur under the dolerite at 122E-036N, and the hillside below is littered with float of laminated chert hornfels.

Feldspathic sandstones with pebbly and conglomeratic phases and interbedded with shaley siltstones are exposed at 200E-043N. The sandstones are olive-grey, medium to fine grained, friable arenites composed of quartz, feldspar and chlorite grains. Feldspar forms up to 30-40% of the rock. The pebbles in the conglomeratic phases are generally well rounded and small, and ellipsoidal mudstone pellets, up to three inches long, are common. The shaley siltstones contain numerous carbonaceous impressions of *? Dicroidium.*

JURASSIC SYSTEM

The central intrusive body within the area is a cone sheet of dolerite (see structural section) of Lower to Middle Jurassic age (McDougall, 1961). Four differentiation zones (Spry, 1958) have been mapped.

The dolerite is blue-grey to greenish in colour and is composed essentially of plagioclase and pyroxene crystals, with accessory iron ore and residual mesostasis. The dolerite is chilled along intrusive margins and is fine-grained and dark grey.

The petrology of the chilled margins and differentiation zones has been extensively investigated by Joplin (1957), Spry (1958), *et al,* and there is little to add except with regard to the behaviour of the Pegmatitic Zone.

The Pegmatitic Zone is not developed in the steep walls of the lower part of the cone sheet except where the sheet flattens out into shelves, such as at Glen Lusk and just behind Chigwell. In these places it is feebly developed some 100 feet below the top contact and is usually less than 50 feet thick. However, where the dolerite rises from this shelf the Pegmatitic Zone, in places, becomes pronounced and comes up almost to the top of the intrusion, the Upper Zone being not more than 10 or 20 feet thick. This is very apparent above the Collins Cap Road at Collinsvale, at 460E-360N and 482E-725N. Pegmatitic dolerite veins, over a foot wide, cut chilled dolerite along the intrusive contact at 490E-616N. The dolerite at 482E-725N rises steeply, and here the Pegmatitic Zone ends 100 to 200 feet above the base of the rise. Thus these upward bends in the cone sheet have acted as concentrating points for the volatiles during differentiation.

The pegmatites contain blades of pyroxene over 10 cm. long in places. They form veins and irregular patches, and the boundaries with the enclosing dolerite are in cases quite sharp. Thin section 30165 cut across such a contact in a specimen from 490E-614N showed ophitic plagioclase (60%) and pyroxene (35%), with mesostasis and iron ore, passing with only slight gradation into coarser plagioclase (45%), pyroxene (30%), and mesostasis (25%), with ophitic to intersertal texture. In the finer zone the feldspar laths average 1-2 mm. in length with zoning from Ab40 to Ab20, and the subhedral pigeonite and augite grains average 2-4 mm. in length. In the coarse zone the feldspar laths (composition Ab20), pigeonite and augite crystals average 4-8 mm. in length, and the mesostasis is Types 1 and 2 (Spry, 1958).

Some of the rocks from the Pegmatitic Zone are very rich in mesostasis. A specimen from Knights Creek Reservoir at 1,031E-2,360N in thin section 30166 shows 70% mesostasis (Type 1 of Spry, 1958).

An interesting dolerite was collected from 300E-649N in the dyke-like body north of Collins Cap. Thin section 30167 shows this rock to consist of a medium-grained mesh of plagioclase (40%) and pyroxene crystals (30%) and mesostasis (25%). The plagioclase laths are mainly from 1 to 1.5 mm. in length, with zoning from Ab40 to Ab20. The pyroxene forms bladed crystals of pigeonite and augite averaging 1 to 3 mm. in length. Many of the pyroxene grains are rimmed with chlorite, and the optic plane is in some cases parallel to 010, and others normal to 010. The mesostasis is mainly Type 2 (Spry, 1958). This specimen is of interest in that no actual pegmatites were observed at this locality. The high mesostasis content suggests that on the steep uprises of dolerite some of the volatile material remains and becomes distributed in the upper zone even though no pegmatites are formed.

TERTIARY SYSTEM

There is a small outcrop of olivine basalt at 9,938E-2,729N and basalt float on silicified Triassic sandstone at 151E-845N. The basalt is presumably Tertiary in age by analogy with other Tasmanian occurrences.

The basalt is vesicular with fillings of chabazite, clay, calcite, and tobermorite minerals. Thin section, 30168, showed euhedral olivine phenocrysts, mainly from 1 and 1.5 mm. in size, in a ground mass of feldspar laths and pyroxene grains, less than 0.3 mm. in size, riddled with grains of iron ore.

QUATERNARY SYSTEM

The Quaternary deposits in the area include scree and talus deposits, soil coverings, and river gravels. The distribution of soils is shown on the Reconnaissance Soil Map of Tasmania, Hobart (1955), Division of Soils, C.S.I.R.O. Deposits of river gravels 15 to 20 feet high are seen in places along the steep gullies of the Sorell River, Humphrey Rivulet, and Knights Creek. A tongue of river gravel covers the lower reaches of Humphrey Rivulet at Glenorchy.

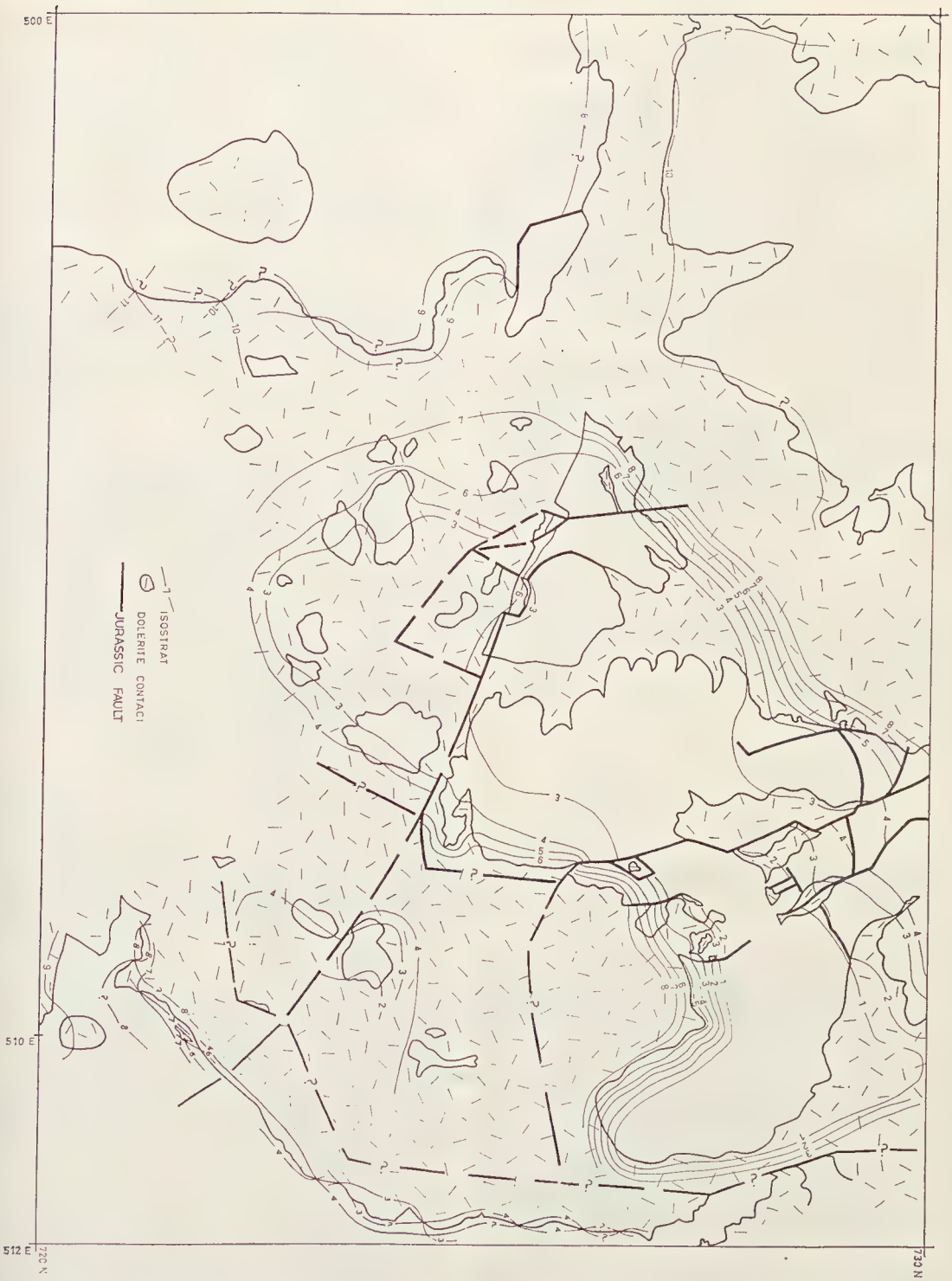

FIG. 2.—Isostrat map of the Collinsvale cone sheet structure. Each isostrat line represents the locus of intersection of intrusive dolerite with the base of a Permo-Triassic formation as follows: 1—Darlington Limestone; 2—Bundella Mudstone; 3—Faulkner Group; 4—Nassau Siltstone. 5—Berriedale Limestone; 6—Grange Mudstone; 7—Malbina Formation; 8—Ferntree Mudstone; 9—Springs Sandstone; 10—Knocklofty Formation; 11—" Feldspathic " Sandstone. N.B.: Around the outer margins of the cone sheet structure, due to insufficient control, alternative sets of isostrats can be drawn and the trends of the isostrat lines are only approximate.

STRUCTURE

1. *STRUCTURAL FEATURES OF THE PERMO-TRIASSIC STRATA.*

These strata are generally sub-horizontal except where dragged against faults. The Triassic System in Tasmania overlies the Permian System disconformably or with a slight unconformity (Banks, 1962 *a*). Variance between the strikes of the two Systems in the Collins Cap area suggests a slight unconformity. A possible unconformity, just to the north-east of the mapped area, has been suggested by Lewis (1946, p. 128). The strike and dip of the Permian beds (with due allowance for fault drags) suggest a gentle basin structure at Collinsvale and possibly an adjoining domal structure east of Glen Lusk.

2. *STRUCTURE OF THE DOLERITE INTRUSIONS.*

The dolerite has intruded the Permo-Triassic rocks in a complex manner, and the intrusions are broken up by Tertiary faulting. The original structure of the dolerite was determined by mapping the dolerite into its differentiation zones and by treating the intrusive contacts according to the "isostrat" method of Carey (1958 *a*) (see Fig. 2).

The Collinsvale Cone Sheet.

In the block bounded by the Cascades and Humphrey's Faults to the east, and the Collins Bonnet and Sorell River Faults to the west, the isostrats fall concentrically inward, indicating a cone sheet centered at Faulkners Rivulet and elongate north-east.

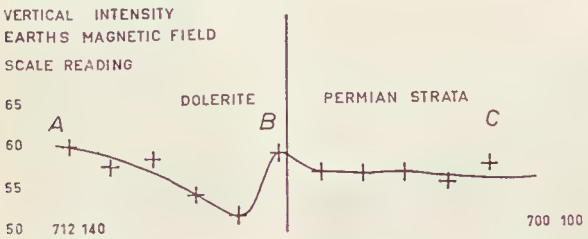

FIG. 3.—Graph of variation in the vertical intensity of the earth's magnetic field observed along traverse across the intrusive dolerite contact west of Oak Hill. The form of the curve suggests the main mass of dolerite is under BC. The small size of the peak compared to the depression is probably due to the subtracting effect of the dolerite at AB.

The eastern and southern walls of the cone rise very abruptly and the contacts are vertical west of Mary's Hope Road and north of Montrose Road. The contact of the southern wall is sill-like in trace above the Collinsvale Road, but was shown to be steeply rising dolerite by a magnetic traverse, along the creek, from 1,140E-2,720N to 1,100E-2,700N (Fig. 3), and by density measurements of dolerite samples collected in a traverse inward from the contact.

The north wall of the cone is less steep, and flattens out into a small shelf just west of Chigwell before rising to form the dyke-like contact below Mt. Faulkner. To the west the dolerite rises against the Glen Lusk Fault, beyond which the cone sheet forms an expansive bowl.

The cone sheet spreads outwards on all sides as an extensive sill-like sheet intruding high Permian or Triassic strata. The sill bodies capping the Mt. Wellington plateau, Mt. Faulkner, the western flank of Collins Bonnet, Collins Cap, and Trestle Mt. are all remnants of this sheet.

The top of the sheet has everywhere been stripped by erosion but the thickness is estimated at about 1,000 feet.

Jurassic Faulting within the Cone Sheet.

Many of the faults within the inner throat of the cone sheet are of Jurassic age, as they stop against dolerite or have unshattered, chilled dolerite or hornfels against them (Fig. 4). No distinctive criteria are present for determining the age of some of the faults, but most of these are probably Jurassic. The faulting within the throat resolves into three stages.

The first stage is faulting of a pre-dolerite age. These faults are cut by dolerite and include the fault at 924E-920N to 831E-856N, the two faults cut by the dolerite mass at 867E-842N, and the fault in the gully between the Collinsvale and Glen Lusk Roads. The eastern end of the last-mentioned fault appears to connect with a thrust fault at 933E-871N. The plane of the thrust dips some 70 degrees to the north-west, and within this thrust block in the quarry at the road junction, is a small "marked horizontal thrust" fault (Lewis, 1946, p. 125). None of the throws on these faults are very large, less than 100 feet for the most part, and they bound an upthrown block in the centre of the cone sheet. This block was presumably upthrust by the intruding dolerite.

The second stage is represented by a system of radial and partial ring faults extending out from the central upthrown block. Radial faults can be seen in the creek beds along the Collinsvale Road at 864E-743N, at 905E-831N, at 845E-925N, and at 933E-874N. The accompanying peripheral faults all downthrow toward the central block. These faults relieved the stress imposed on the rocks by the intrusion of the dolerite cone. In places the dolerite took advantage of these structural weaknesses and its form was partially controlled by the concomitant faulting.

The Glen Lusk Fault represents the third stage of the faulting and is a strong tangential fracture marking off the inner throat of the cone sheet. It throws down toward the central part of the cone. The throw is just over 100 feet at the north end, whereas to the south the throw increases to 250 feet. Later Tertiary movement along part of the fault probably accounts for the increase. The fault was an important line of intrusion for the dolerite.

A series of faults branches off the north end of the Glen Lusk Fault and these abut against the dolerite wall rising up to Mt. Faulkner. The fault on the ridge at 731E-931N is a thrust, the fault plane dipping some 70-80 degrees to the south. The throws of these faults increase as they approach the dolerite wall.

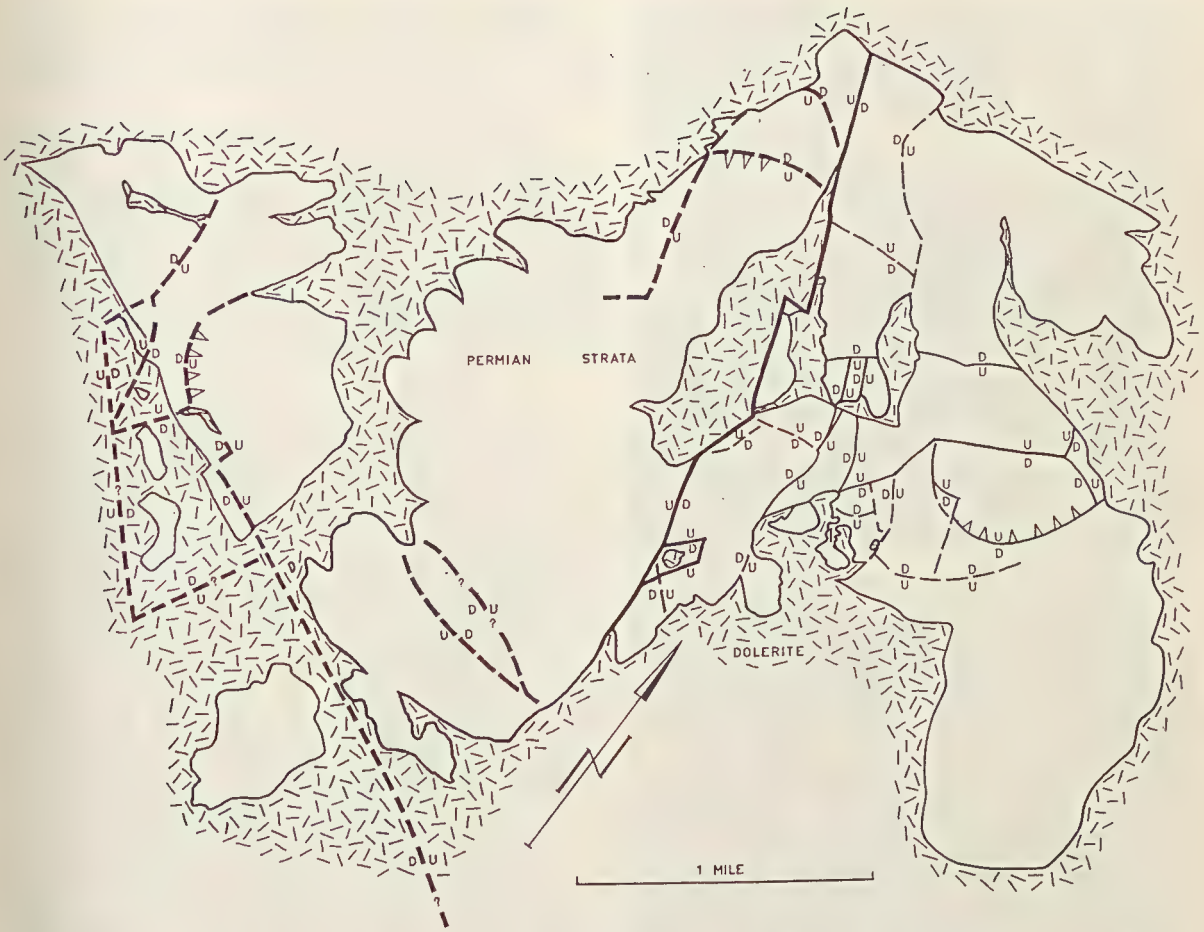

FIG. 4.—Map showing the concomitant faulting within the dolerite cone sheet. The thin unbroken fault lines represent the first stage of the faulting, i.e., the upthrown block within the throat of the cone; the thin broken lines the second stage, i.e., the radial and partial ring faulting; the thick unbroken lines the third stage, i.e., the tangential Glen Lusk fault; and the thick unbroken lines the faulting associated with the Collinsvale basin sructure.

Concomitant faulting is associated with the upstepping of dolerite west of Collinsvale. A fault beginning at 538E-678N stops at a small plug of dolerite at 553E-604N sidesteps to the south-west, then continues and is cut off by dolerite at 629E-567N. The fault is a thrust west of the dolerite plug. The fault plane dips about 70 degrees east and the throw is 150 feet. East of the dolerite plug the nature of the fault is not evident and the throw is 200 feet. The structure is interpreted as a line of thrusting giving way laterally to a zone of tension up which rose the plug of dolerite.

A physiographic high in the dolerite to the south-east forms an extrapolation of this line of faulting and suggests it continued right across the cone sheet. The high shows up as a strong linear on the aerial photographs and passes out of the dolerite as the fault in the cheek at 1,031E-2,307N. This fault has the same amount and sense of movement as on the fault at Collinsvale. No brecciation of the dolerite is visible where the linear crosses Knights Creek and it marks a petrographic change in the dolerite from a differentiate on the elevated side, characteristic of central levels of the dolerite body, to a differentiate, on the subjacent side, typical of a higher level. All this suggests Jurassic faulting concomitant with an upstepping of dolerite. Block subsidence associated with this line of faulting (Fig. 4) is suggested by the dislocation of isostrats to the south-west. The apparent dislocation may be caused by the inward dip of the strata toward the centre of the basin structure at Collinsvale, but calculations suggest that dips of about 15 degrees would be required. This is somewhat higher than the observed dips. Subsidence following upthrusting is also compatible with the same behaviour inferred in the faulting within the throat of the cone sheet.

The fault at 493E-682N downthrows 150 to 200 feet to the west, and the throw diminishes southward. Dolerite is intruded up into the beds on the downthrown side, but does not appear in the beds on the upthrown side. This fault is possibly another thrust concomitant with an upstepping of dolerite.

Influence of the Permo-Triassic Structure on the Cone Sheet Intrusion.

The cone sheet appears to have intruded up into a dome of Permian strata. The doming was possibly caused by the vertical push of the intruding dolerite, but the indications of an unconformity between the Permian and Triassic strata in the area suggest it was possibly epi-Permian folding. The cone sheet near Geeveston is also centered in a dome of Permian strata (see Banks 1962 *a*) and there is some suggestion that the cone sheet at Bloomfield occupies a domal structure (see Anand Alwar, 1960). This may be a purely fortuitous association but there is a possibility that the domes exercise a selective control as sites of intrusion, since their potential for relief of upward stress through radial and concentric fracturing is greater than that of basins.

The intruding dolerite pushed out the top of the dome, i.e., the central upthrust block, and the upward stress was relieved by the radial and concentric fracturing. Where the dolerite cone met the adjoining basin structure to the west the rocks fractured along the Glen Lusk Fault, suggesting that the basin structure imposed a greater resistance to the upward passage of the dolerite.

Beyond the Glen Lusk Fault the intrusion appears to have been controlled by the basin structure, and it expands out into a basin-shaped sill. The dolerite, finally, breaks through the strata along the thrusts north of Glen Lusk and at Collinsvale, the latter thrust forming a fracture for the uprising of magma across the whole cone sheet. The thrusts suggest intrusive pressure, possibly built up by the dolerite flowing downward into the basin structure.

Dolerite Intrusions joining the Cone Sheet.

The western side of the cone sheet is met by a dyke-like body north of Collins Cap, and the fault at 191E-625N is probably a concomitant fracture. This dyke-body is formed at the meeting of intrusions rising from the north and from the south. It is joined to the south by a transgressive sill that intrudes the Grange Mudstone in the Mount Rivulet at 004E-511N. The Collins Cap Fault was concomitant with this intrusion. It downthrows 200 feet at Collins Cap, but the throw decerases northward where it splits into several small faults against the dyke-body.

The dyke-body is joined on its northern side by a sill appearing in Triassic strata at 227E-858N and by an intrusive mass west of Malbina. The country between is broken by concomitant faulting, apparently under a tensional stress that operated across the two dolerite uprisings. A source of these northern intrusions is presumably the sill that rises from low in the Permian System north of the Derwent River (Read, 1960).

A plug of dolerite, in the Sorell River at 471E-940N, rises up to join the Mt. Faulkner sill body. This is either an off-shoot of the cone sheet from below river level or a feeder from the sill north of the Derwent River.

There are several possible interpretations of the line of intrusion from north of Collins Cap to south of Collins Bonnet. The intrusion consists of a lower dyke-body and a higher-sill body that caps Trestle Mt. and Collins Cap. A pocket of Triassic sandstone at 347E-342N has been downthrown by at least 200 feet in relation to the sandstones of Collins Cap and is separated from them by dolerite. This displacement is either dilational or caused by a Jurassic fault beneath the dolerite. These contacts may represent:

(1) The base of the ascending cone sheet,
(2) The dolerite sill in the Mount Rivulet rising up to meet the cone sheet,
(3) The cone sheet and the Mount Rivulet sill joining and rising as a dyke before turning outward as the sill body.

None of these three cases can be chosen on a consideration of dilation effects, as all of the thicknesses of the dolerite bodies are not known. The dolerite of the Collins Bonnet massif and Trestle Mt. falls trangressively to the south-west, and another interpretation is that here the cone sheet is arching over and falling in the opposite direction, as in the Scott Arch of the Huonville cone sheet (Carey, 1958 *a*).

The dolerite contact along Tolosa Street can be shown by the relative displacement, through faulting, of intrusive contacts and differentiation zones, to be sloping down to the east. Thus this contact may represent the upstepping of a sill rising from the east. A sill rising from the northeast intrudes Grange Mudstone in the Lenah Valley area (Lewis, 1946, p. 95) and extrapolation of this sill indicates that this would also be the stratigraphic level of intrusion at Tolosa Street. If this is the case then the blocks of Permian rocks exposed underneath Mt. Hull at 900E-418 N and at 922E-444N are probably "windows" in the base of the sill where it rises to meet the cone sheet in an arch structure along the line of Mt. Hull. The Mt. Wellington sill extends outward from this arch-like meeting. Thus there are two sill sheets in the same vertical section at the northeast spur of Mt. Wellington, the lower one intrusive into Grange Mudstone, and the higher one intrusive into the top of the Ferntree Mudstone and the base of the Triassic System.

The low stratigraphic level of the rocks beneath the floor of the sill rising from Tolosa Road as compared with the roof rocks is the reverse of what would be expected on dilational grounds. Thus it appears the sill rose up along a large Jurassic fault. It is likely that Humphrey's Fault is the old Jurassic fault with renewed Tertiary movement. Humphreys Fault joins the Cascades Fault which in the nearby Claremont area is Tertiary movement along a Jurassic fault line (Read, 1960). The Glen Lusk-Hull Fault line also appears to be Tertiary movement along a Jurassic fracture that joined Humphrey's Fault.

The pattern of intrusion in the mapped area, with regard to the approach of intrusive bodies on almost all sides, places the cone sheet as a major intrusive centre in the Hobart district.

3. *THE POST-DOLERITE TENSIONAL FAULTING.*

The age of the post-dolerite tensional faulting in Tasmania is late Mesozoic and/or early Tertiary with continued movement throughout the Cainozoic (Banks, 1962 *b*, Solomon, 1962). The dominant trend in the faulting is north-westerly (Banks, 1958 *b*), but there is no marked preference for this trend in the mapped area and the controlling factor is the Jurassic structure. Steep dolerite margins and Jurassic faults regulate most of the faulting.

The Cascades-Humphrey's-Austin's Fault System.

The first phase of tensional failure under the Tertiary epeirogenic stresses was faulting along old Jurassic faults that followed the circumference of the cone sheet. The Cascades Fault (Lewis, 1946) changes abruptly in trend just west of Rosetta Road where it approaches the cone sheet, and then faults the north-east margin of the cone sheet. The throw here is at least 2,200 feet down to the east and probably about 3,000 feet. Humphrey's Fault (Lewis, 1946) follows the eastern and south-eastern margin of the cone sheet but the throw cannot be determined. It is marked by a distinct scarp and the fault probably continues up onto the Mt. Wellington plateau upthrowing the Mt. Connection block. Austin's Fault (Lewis, 1946, p. 98, not as marked on his map) also parallels the south-east margin of the cone sheet and downthrows 300 to 350 feet to the west.

The Collinsvale-Hull Fault System.

Adjustment fracturing at right-angles to the faults following the circumference of the cone sheet gave a system of radial faults that cut across the dolerite margins and the earlier faults. The important faults of this system are the Collinsvale, Hull (Lewis, 1946), Valleydale (Lewis, 1946) and Knights Creek Faults. The Collinsvale Fault is a major fault that continues westward across the whole of the cone sheet and out of the mapped area. It is not the Collinsvale Fault as defined by Lewis (1946), which does not exist—Lewis mistakenly took the intrusive inner margin of the cone sheet for a fault contact.

Most of the radial faults link up with the Collinsvale Fault through cross-fractures. Patches of roof rocks east of the cross fault at 950E-530N indicate a downthrow of about 500 feet to the east. The Hull Fault terminates at 891E-622N, where it splits into several faults, and some of the tension was taken upby movement along part of the Glen Lusk Fault.

A feature of the Collinsvale Fault, along the Collins Cap road, is the adjustment cross-faulting. The largest adjustment faulting, however, took place where the Collinsvale Fault passes out of the cone sheet. On the southern upthrown side the adjustmat was made by a downthrow of the cone sheet (Collins Bonnet Fault), while on the north downthrow side adjustment was made by uplift (Sorell River Fault). From here the Collinsvale Fault follows the margin of the dolerite dyke-body north of Collins Cap, its upthrow side forming a steep and high scarp.

Collins Bonnett-Sorell River Faults.

The Collins Bonnet Fault is difficult to prove conclusively. The outcrop of Triassic sandstone at 347E-342N is cut off against dolerite to the east. This appears to be a fault contact rather than an igneous one, but the exposure is not sufficiently good for certainty. A small physiographic trough joining this exposure to the Collinsvale Fault suggests the presence of a fault. Further along this line, on the saddle between Mt. Connection and Collins Bonnet, there is an apparent change from Upper Zone dolerite to a dolerite rich in ferromagnesians, that probably represents a lower differentiation zone. If this change is caused by faulting, then a tentative estimate of the throw would be 600 feet down to the east.

The Sorell River Fault is expressed by a saddle seen in the Sorell River gorge, and the fault terminates in a downthrown wedge formed by cross-faulting.

4. *JOINTING*

Jointing in the Dolerite.

The characteristic columnar jointing of the Tasmanian dolerites is well developed in the dolerite sheets of Collins Bonnet, Collins Cap, and Trestle Mt. This jointing has been regarded as a system of cooling joints (Hale, 1958), but Carey (1958 *b*) regards it as an expression of epeirogenesis.

The jointing in the dolerite is often blocky, as the rock is also cut by strong sub-horizontal joints. Inclined and curved fractures are also common. Close vertical jointing is common along intrusive margins and extends into contact hornfels, as at 527E-722N, where it has obliterated the bedding in baked Bundella Mudstone.

Joint planes are smooth or show fluting and surface roughness. Calcite and zeolites form common joint fillings. Chabazite is very common, stilbite is found near 427E-638N, and the rare zeolite, gonnardite, occurs at Knights Creek. As far as is known this is the first recorded occurrence of gonnardite from intrusive rock.

Measurements of joint directions were taken at 60 feet intervals commencing at the base of the sill rising up onto Mt. Wellington along Humphrey Rivulet. Curved joints, considered to be mainly cooling joints, were not measured because of the difficulty of plotting strikes. Approximately 225 joint directions were taken.

The joint pattern (Fig. 5*b*) shows two major directions of near vertical joints, a set at 330 degrees and a set at 275 degrees. The set at 330 degrees corresponds well with the dominant Tertiary trend of tensional failure (Banks, 1958 *b*). The east-west trend has been reported by McDougall (1959) and Rodger (1957). There is some development of jointing normal to both these trends. There are also joints dipping approximately 20-30 degrees to the north-west. These

joints probably developed parallel to the base of the sill sheet, which is transgressive upward to the south-east. The relationship between the joint pattern and the Tertiary faulting in the vicinity is not complete. The set at 330 degrees is in accord with the trends of the Knights Creek and Valleydale Faults just to the north, and the set at 275 degrees is possibly related to the fault across Humphrey Rivulet at 847E-158N. However, there is little expression in the joint pattern of the Humphrey's and Austin's Faults.

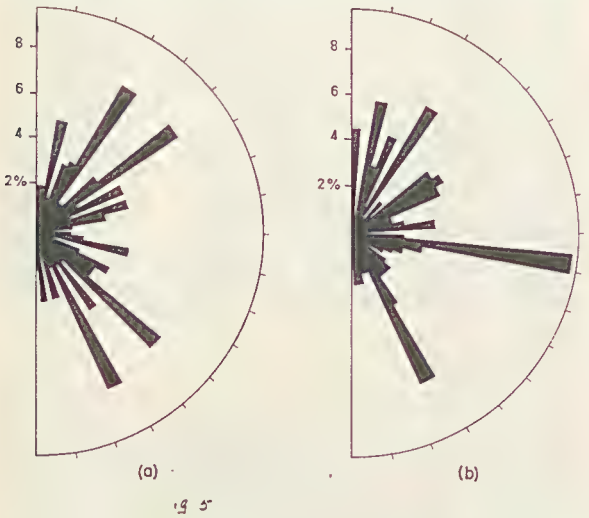

FIG. 5.—Joint frequency diagrams—Humphrey Rivulet (*a*) Permian strata, (*b*) Jurassic dolerite.

Jointing in the Permo-Triassic Strata.

The Permo-Triassic rocks, as elsewhere in Tasmania, are cut by strong vertical cross-jointing with subsidiary inclined fracturing. Two joint directions are generally dominant, intersecting at angles between 70 and 90 degrees. A third median vertical direction is present in many cases. In places only one of the joint directions is well developed as in the pavement of Ferntree Mudstone exposed at 482E-922N.

Where the strata are inclined the jointing is always normal to the bedding. This is well illustrated at 478E-627N, where beds of the Malbina Formation are dragged up against the Collinsvale Fault and dip at about 30 degrees. Thus the jointing was either imposed prior to the Tertiary faulting or formed as radial tensional joints on the bend of the fault drag.

Joint directions were taken in the Permian rocks outcropping in Humphrey Rivulet below the dolerite sill sheet. Measurements were made at 25 feet intervals and approximately 150 readings were taken. The joint pattern (Fig. 5*a*), although not very strongly developed, gives the characteristic directions at 210 and 310 degrees, and a median direction at 230 degrees. There is a joint direction corresponding to the major Tertiary trend at 330 degrees. The pattern is similar to that of the jointing in the Permian rocks in the South Arm-Sandford area (Green, 1961).

The joint pattern for the Permian rocks in Humphrey Rivulet when compared with the pattern for the jointing in the overlying dolerite sheet shows similarities, but the correspondence is not marked. The major Tertiary trend is present in both patterns at 330 degrees, but examination of the readings taken in the Permian rocks showed that most of the joints of this trend occur in the contact hornfels at both ends of the outcrop. Lack of correspondence between joint direction trends in Permian strata and dolerite bodies also occurs in the joint patterns for the South Arm-Sandford area (Green, 1961) and the Pontville-Dromedary area (McDougall, 1959). These facts tend to suggest that the sedimentary strata and the dolerite failed under the Tertiary tensional stresses in differing manners. The most obvicus inference is that the sedimentary strata failed in part by shear jointing, while the more brittle dolerite and contact hornfels failed by tension jointing. Some of the jointing in the Permian rocks is probably related to the epeirogeny and dolerite intrusion in the Jurassic. It is noticeable that the trend of the steep dolerite contact across Humphrey Rivulet is approximately parallel to the jointing trend at 310 degrees. Also the trends of Humphrey's and Austin's Faults and of the dolerite contact along Tolosa Road are approximately parellel to the jointing trend at 230 degrees.

5. *BASALT LAVA FLOW*

The remnants of Tertiary basalt at 151E-845N and at 9,938E-2,729N indicate a flov sloping down to the north. The Collinsvale Faul: was probably the line of ascent of the lava.

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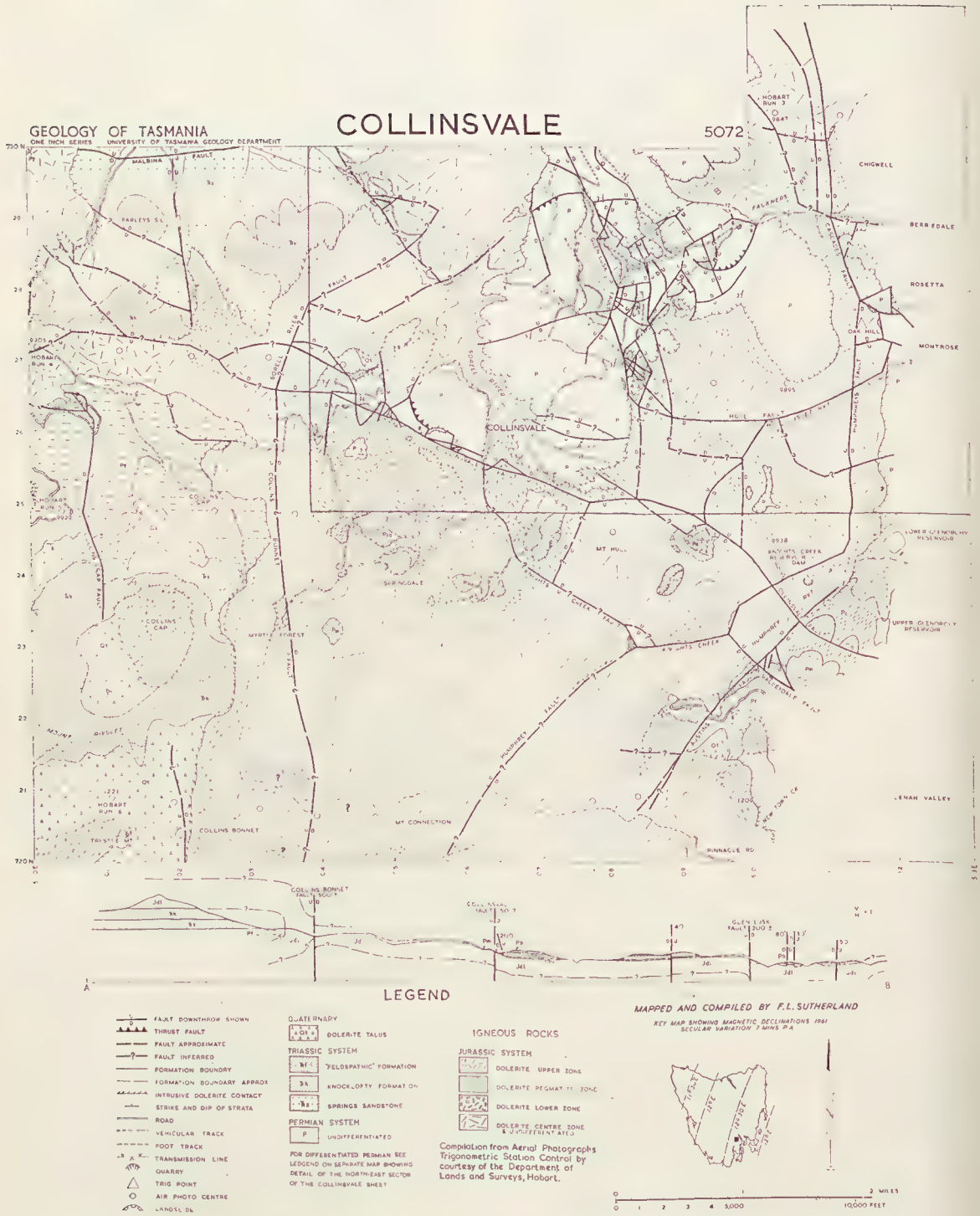

N.B.—This map is part of a one-inch series, but the scale in this paper has been reduced by approximately one quarter.

QUATERNARY SYSTEM
Qd DOLERITE TALUS
TRIASSIC SYSTEM
Rk KNOCKLOFTY FORMATION
Rs SPRINGS SANDSTONE
PERMIAN SYSTEM
Pf FERNTREE MUDSTONE
Pr RISDON SANDSTONE
Pm MALBINA FORMATION
Pg GRANGE MUDSTONE
Pb BERRIEDALE LIMESTONE
Pn NASSAU SILTSTONE
Prg RAYNOR SANDSTONE
Prg FAULKNER GROUP
Pbu BUNDELLA MUDSTONE
Pd DARLINGTON LIMESTONE
Ps SATELLITE SILTSTONE
Pw WOODY ISLAND SILTSTONE
Pfg CASCADES GROUP
JURASSIC SYSTEM
Jdl DOLERITE
FAULT
THRUST FAULT
INTRUSIVE DOLERITE CONTACT
TRANSMISSION LINE
STRIKE & DIP OF STRATA
½ MILE
N
FAULKNERS
OAK HILL
COLLINSVALE
SORELL RIVER
RIVULET

D. E. WILKINSON, Government Printer, Tasmania.

PAPERS AND PROCEEDINGS

OF

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1965.

The Royal Society of Tasmania

Volume 99

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Royal Society of Tasmania

Papers and Proceedings Volume 99

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Royal Society of Tasmania

Annual Report for the year 1964.

On behalf of the Council of the Royal Society of Tasmania the following Annual Report is presented to members.

His Excellency the Governor.

When the Society was formed in 1843 His Excellency the Lieutenant-Governor Sir Eardley Eardley-Wilmot, consented to become President. Since then successive Governors have accepted the office of President and it was with considerable pride that the Council was informed that His Excellency Sir Charles Gairdner, the present Governor of the State, had indicated his willingness to accept office. He presided at the Annual Meeting, briefly addressed members, and met members at the conclusion of the meeting.

Annual Meeting.

The Annual Meeting was held as a special meeting for members only. The following office-bearers were elected to fill the vacancies created by those whose term of office ended, and by Rule of the Society were not available for re-election:—

Vice-President—Mr. E. C. Gifford.

Members of Council—Mr. R. A. Both and Mr. E. R. Pretyman.

The following were re-elected:—

Honorary Secretary—Dr. W. Bryden.

Honorary Treasurer—Mr. G. E. A. Hale.

Honorary Auditor—Mr. A. M. Hewer.

General Meetings.

The following addresses were given at the General Meetings:—

March: Professor G. C. Wade, University of Tasmania, on "*Useful Fungi*".

April: Dr. E. M. Colbert, American Museum of Natural History, New York, on *Dinosaurs*".

May: Dr. A. K. Fryer, University of Tasmania, on "*Political Science as a Science*".

June: Dr. G. Reber, Honorary Research Fellow, Research Corporation, New York City, on "*Astronomy—an Intellectual Endeavour*".

July: Dr. R. F. Cane, University of Tasmania, on "*Colour—Variations on a Chromatic Theme*".

August: Mr. M. S. R. Sharland on "*The Waters of Canada*".

September: Mr. V. W. Hodgman, Tasmanian Museum and Art Gallery, on "*Australian Artists represented in the Collections of the Royal Society and the Museum*".

October: Dr. O. M. Roe, University of Tasmania, on "*The National Association of Great Britain for the Promotion of Social Science*, 1857-84".

November: Mr. J. Boothroyd, University of Tasmania, on "*The Language of Computers*".

Special Meetings.

Four special meetings were held, the speakers being as follows:—

June: Mr. J. L. Davies, University of Tasmania, on "*The Shape of Spits*".

July: Dr. J. Cosgriff, University of Tasmania, on "*Triassic Vertebrates of Australia*".

August: Mr. C. Bisdee, on "*Man in Space*".

September: Dr. K. C. Marshall, University of Tasmania, on "*What are Bacteria?*"

Vacancy on Council.

Professor Clark resigned when he left to take up his appointment in Adelaide and at a General Meeting Mr. G. K. Meldrum was elected to fill the vacancy.

Library.

Further additions were made to the library during the year, the total additions for the year being 640 volumes.

Additional volumes were bound and this practice will be continued in the future. Each year there is an increasing demand for information which is available in the various books, papers, letters, documents, &c., in the Library. The actual value of the Society's collection has increased materially over the years and by all standards it is obvious that in the Royal Society Library there is indeed a very valuable historical collection of which the State should be proud.

Northern Branch.

In Launceston, the Northern Branch again had a very interesting and useful year. In addition to the evening lectures, a number of excursions to places of historic and scientific interest were arranged for the benefit of members.

Membership.

The total membership of the Society now stands at 625.

Papers and Proceedings.

Volume 98 of the "Papers and Proceedings of the Royal Society of Tasmania" was printed during the year. It is largely by exchanging our volume for publications put out by other institutions that we manage to keep the library to its high standard. The number of exchanges is 316.

Acknowledgements.

The Council wishes to place on record its appreciation of the work carried out by the Staff and by all those who help our activities in so many ways. Council appreciates the continued interest and active support given by the Government of Tasmania, the University of Tasmania, the Tasmanian Museum and Art Gallery, the Queen Victoria Museum and Art Gallery, the Press and Radio Stations, and also extends sincere thanks to all others who have rendered assistance during the year.

Northern Branch

Annual Report, 1964.

Following the Annual General Meeting of the Northern Branch, held on 20th March, 1964, the Branch Council was composed as follows:—

Chairman—Mr. T. E. Burns.
Vice-Chairman—Mr. Justice G. H. Crawford.
Past-Chairman—Mrs. I. J. Mead.
Honorary Secretary and Treasurer—Mr. W. F. Ellis.
Members of Council—Mr. A. W. G. Powell, Dr. N. Gold, Mr. P. M. Hart, Mr. G. H. Stancombe, Mr. F. L. Sutherland.

Mr. Burns and Mr. Ellis represented the Branch on the General Council of the Society and Mr. Ellis also served on the Standing Committee. Mr. Justice Crawford continued as the Northern Branch nominee on the Cradle Mountain-Lake St. Clair National Park Board.

Membership.

On 31st December, 1964, the Northern Branch comprised 13 Life Members, 237 Ordinary Members and 9 Associate Members representing an increase of 5 in the total during the year.

Activities.

Eleven General Meetings were held at which the attendance averaged 70 persons. The following papers were read:—

21st February, 1964—"A Pastoralist's View of Central and South America" by Mr. R. E. Lawrence.

20th March, 1964—"An Early Settlement in the North of Van Diemen's Land" by Mrs. I. J. Mead.

17th April, 1964—"Some Problems of Fruit Development" by Professor C. A. Schroeder.

1st May, 1964—"The Introduction of the Salmonidae to Tasmania" by Mr. D. Scholes.

3rd July, 1964—"The Three Scotts: James, Thomas & George" by Mr. Justice G. H. Crawford.

31st July, 1964—"Caves in France" by Mr. R. D. Woolhouse.

21st August, 1964—"The Historians of Tasmania" by Mr. G. H. Stancombe.

25th September, 1964—"The Tasmanian Thylacine" by Dr. E. R. Guiler.

23rd October, 1964—"Hovercraft and Vertical Take-Off Aircraft" by Group Captain F. B. Sutton.

27th November, 1964—"Man In Space" by Mr. Colin Bisdee.

11th December, 1964 (Member's Night)—

"Ancient Peru" by Miss M. Mack.

"G. V. Brooks and the Development of Education in Tasmania" by Mr. D. V. Selth.

"Pathology" by Dr. D. D. E. Evans.

"A Trip from Campbell Town to Hagley in 1849" by Mr. E. G. Scott.

"Wandering Pumice" by Mr. F. L. Sutherland.

Four excursions were arranged, including one spread over a long weekend. These were to—

Mathinna—15th March, led by Mr. Justice Crawford.

Deloraine and Cheshunt—12th April, led by Mr. J. R. Skemp.

"The Examiner"—21st September, by courtesy the Proprietors.

St. Helens and Ansons Bay—31st October-2nd November.

These excursions have all been well attended.

Council.

The Northern Branch Council met five times during 1964. In addition, the Branch was represented at the five meetings of the General Council, including one convened in Launceston.

Acknowledgements.

The Branch Council records its gratitude to the Launceston City Council for the facilities at the Queen Victoria Museum which have been provided during the year.

ON PLANARIVORA INSIGNIS GEN. ET SP. N. (DIPTERA: MYCETOPHILIDAE), WHOSE LARVAL STAGES ARE PARASITIC IN LAND PLANARIANS

By

V. V. Hickman

(With one plate and 22 figures in the text.)

ABSTRACT

Planarivora insignis gen. et sp. n. is a Dipteron belonging to the family Mycetophilidae. The female is about 8.0 mm. long. The head and antennae are black, thorax and first abdominal segment reddish brown, the other abdominal segments black. The wings are fuscous and have a venation like that of *Cerotelion* Rond. The three basal segments of the legs are reddish brown, tibiae and tarsi black. The male resembles the female but the thorax is black. The larval stages are parasitic in certain land planarians, namely *Geoplana tasmaniana* (Darwin), *Geoplana mortoni* Dendy and *Geoplana diemenensis* Dendy.

The adult flies emerge during January and February. The females lay their eggs in places where the land planarians occur. The first stage larva penetrates the body of the planarian by means of powerful mandibles and numerous hook-like spines situated at the front of the prothorax. Having entered the body of the planarian the larva grows very slowly during the period April to November. It then undergoes ecdysis giving rise to the second stage larva, which grows rapidly as it feeds on the internal organs of the planarian. Eventually the parasite kills its host, and bites its way out of the body. It then creeps into a crevice under a stone or in a rotten log and spins a frail meshwork of threads, in which it pupates. Pupation takes places towards the end of December and early in January. It lasts about eight days. Locality: Fern Tree, Mount Wellington, Tasmania.

INTRODUCTION

The little that is known concerning the Tasmanian Mycetophilidae appears mainly in the systematic studies of Skuse (1888), Ferguson (1925), Edwards (1929) and Tonnoir (1929). With regard to the biology of our local species nothing seems to have been recorded.

The larvae of most Mycetophilidae feed on fungi. In fact Landrock (1940) states: "Die Pilzmückenlarven sind ausnahmlos auf vegetabilische Kost angewiesen". In making this statement he appears to have been unaware of the work of Mansbridge (1933), who has shown that a carnivorous habit is present in at least three subfamilies of fungus flies, namely, Ceroplatinae, Macrocerinae and Bolitophilinae. In some cases the larvae spin webs for capturing the small myriapods, insects &c., that form their pray. In the webs of certain species of *Platyura* and *Ceroplatus* liquid droplets are suspended. These droplets have been shown by Buston (Mansbridge, 1933) to contain oxalic acid in sufficient strength to kill small insects coming into contact with it.

Planarivora insignis gen. et sp. n. described in the present paper is remarkable in having larvae that are parasitic in the body of certain terrestrial planarians, namely, *Geoplana tasmaniana* (Darwin), *Geoplana mortoni* Dendy and *Geoplana diemenensis* Dendy. Prior to pupation the larva kills and almost completely devours its host.

METHODS AND MATERIALS

Specimens of *Geoplana tasmaniana* (Darwin) were collected at Fern Tree, Mount Wellington, nearly every month of the year. They were brought to the laboratory and examined under a dissecting microscope. In infected specimens, that were not too heavily pigmented, it was often possible to see the dark head of the larva as the parasite moved about within the body of the planarian. In other cases it was necessary to dissect the planarian in order to determine whether or not it was parasitized.

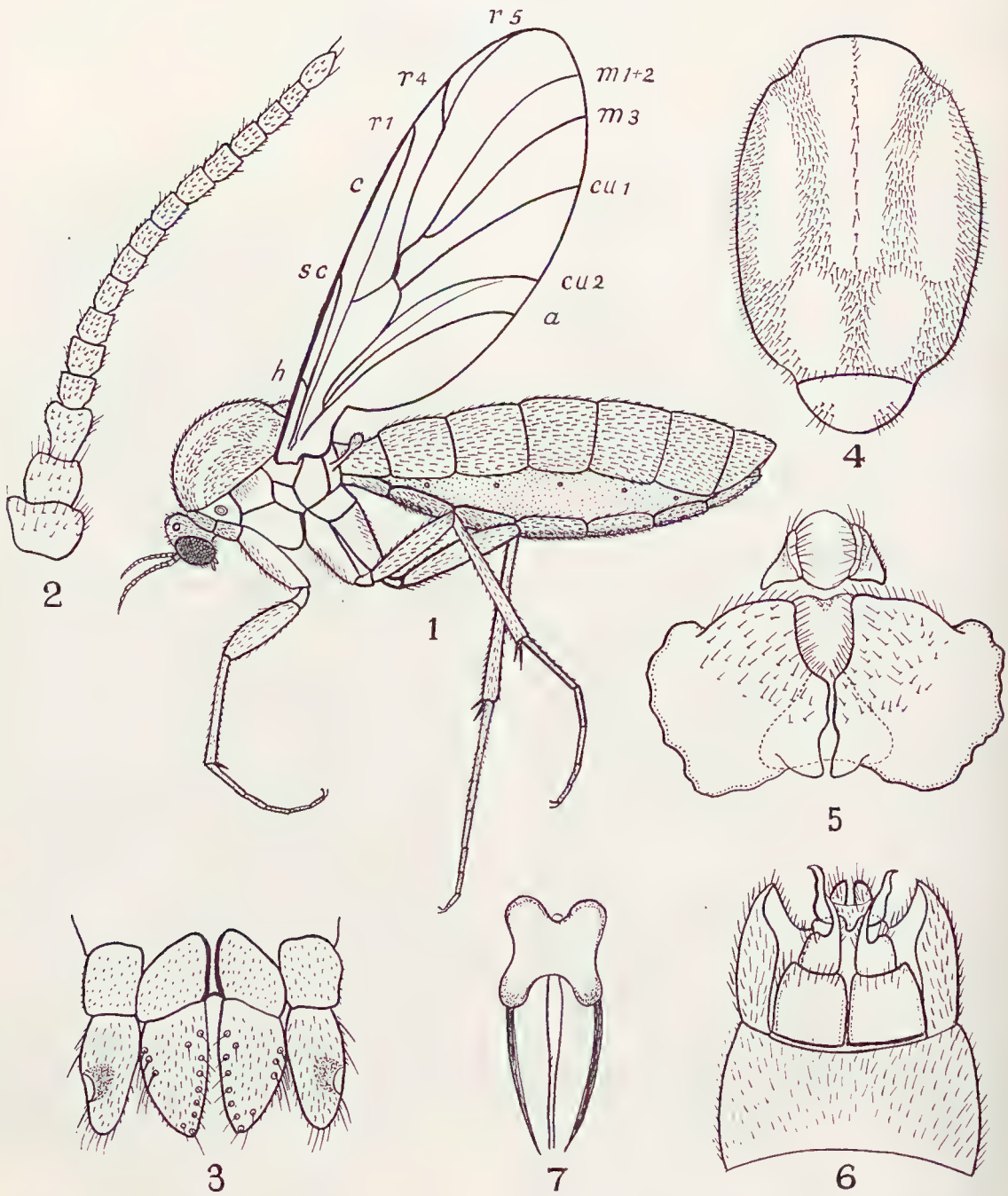
Some infected specimens of the planarian were kept amongst moss and rotten wood in small vivaria until the mycetophilid larva emerged and pupated. A number of adults were bred from pupae thus obtained and also from pupae collected in the field.

Adults of both sexes were kept together in vivaria containing moss, ferns, rotten wood &c., brought from the natural habitat. Non-infected specimens of *Geoplana tasmaniana* were also placed amongst the materials in the vivaria. It was thought that under these conditions males and females of the mycetophilid might mate, but no mating was observed to occur.

The features of adults and larvae were studied in both living and preserved specimens. Whole mounts of dissected parts were prepared for examination under the microscope. Some of the larvae were fixed in Bouin's fluid and cut in serial sections at a thickness of 10 micra. The sections were stained with Ehrlich's haematoxylin and eosin.

Family: Mycetophilidae
Sub-family: Ceroplatinae
Genus: **PLANARIVORA gen. n.**

Face broad. Compound eyes oval. Three ocelli in a curved line. Antennae short, with 2 + 14



Planarivora insignis sp. n.

Imago

FIG. 1.—Female showing wing venation.
FIG. 2.—Antenna.
FIG. 3.—Palpi and proboscis.
FIG. 4.—Mesonotum from above.
FIG. 5.—Ovipositor and anal segment of female from below.
FIG. 6.—Hypopygium and anal segment of male from below.
FIG 7.—Aedeagus from above.

segments; flagellum rounded and tapering. Proboscis short and withdrawn. Palpi straight and two segmented; basal segment distinct, apical segment thickened and having a large concave sensory pit. Wings clothed with microtrichia; a few longer setae on the veins and in the anal region. Venation like that of *Cerotelion*, *r*4 ending in costa beyond the apex of *r*1. Pleurotergites bare. Middle and hind tibiae slightly enlarged from base to apex. First tarsal segment of hind legs not thickened. Abdomen with seven complete segments in female, eight in male. Larva apodous, peripneustic and parasitic in land planarians. Genotype: *Planarivora insignis sp. n.*

The new genus *Planarivora* is close to *Ceroplatus* Bosc and *Cerotelion* Rond but differs from them in the form of the antennae, palpi and genitalia of the adult and also in the larva being peripneustic and parasitic.

Planarivora insignis sp. n.

Female (Text-fig. 1).

Length (without antennae) 8.0 mm.

Colour: Head and antennae black. Thorax and first abdominal segment reddish brown. Second to seventh abdominal segments with black tergites and sternites. Coxae, trochanters and femora of legs reddish brown; tibiae and tarsi black. Tibial spurs black. Wings fuscous.

Head small, broad and directed forwards and downwards. Compound eyes oval and well separated. Three ocelli in a curved row. Surface of head and compound eyes finely pubescent. Antennae short, about 1.03 mm. long, with 2 + 14 segments. The flagellum rounded and tapering slightly towards the apex. It is clothed with short fine hairs (Text-fig. 2). Palpi short, straight and two-segmented. The distal segment is enlarged, pubescent and furnished with a few bristles. It has a large concave sensory organ on its outer side (Text-fig. 3). The proboscis is short and withdrawn.

Thorax high and strongly arched due to the pronounced convexity of the mesonotum (Text-fig. 1). Pronotum small, pubescent and partly concealed beneath the front of the mesonotum. Its anterior and posterior divisions are separated by a groove. The surface of the mesonotum exhibits pubescent and hairless regions as shown in Text-fig. 4. Scutellum small and almost semicircular with a few hairs on each side. Postnotum steep, slightly arched and smooth. In the pleural region the anepisternite has a few short hairs on its upper part immediately behind the spiracle. The other pleura are smooth and bare.

Wings: Length 6.2 mm., greatest width 2.3 mm. Surface clothed with microtrichia and a few scattered macrotrichia especially in the anal region. The margin and veins also bear small setae. The venation (Text-fig. 1) resembles that of *Cerotelion*. The costa extends to the apex of the wing. A small humeral vein is present. The sub-costa opens into the costa at about one third of the wing length from the base. The radius has three branches *r*1, *r*4 and *r*5. The first branch *r*1 opens into the costa at slightly more than two thirds of the wing length from the base. The branch *r*4 enters a short distance beyond the apex of *r*1. The branch *r*5, which is more than twice the length of *r*4, enters the costa a little before the apex. The basal stalk of the media is pale and indistinct, the vein appearing to arise from *cu*1 and to fuse for a short distance with the radial sector, before dividing into two branches *m*1 + 2 and *m*3. The cubitus forms two branches *cu*1 and *cu*2. The anal vein *a* is complete and extends to the posterior margin of the wing. Between *a* and *cu*2 the wing forms a fold. An axillary vein is lacking. The halteres measures 0.86 mm. long. The rounded apex is finely pubescent and the stalk has a few longer setae.

Legs: The measurements of the segments in mm. are as follows:—

	Leg 1	Leg 2	Leg 3
Coxa	0.91	0.91	0.97
Trochanter	0.28	0.28	0.28
Femur	1.14	1.65	1.83
Tibia	1.31	2.00	2.46
Tarsus	1.94	2.74	2.97
Total	5.58	7.58	8.51

The coxae are elongate, those of the third pair of legs being nearly half the length of the femora. The anterior coxae are pubescent for their full length in front, the middle coxae on the apical half in front, and the hind coxae lightly pubescent on the outer side. Tibiae are slightly and uniformly expanded towards the apex. The second and third pairs are furnished with a dorsal, an inner and an outer row of very short setulae amongst the general pubescence. There is a single ventral spur at the apex of the first tibiae and a pair of ventral spurs at the apex of the second and third tibiae. The tarsi are five segmented, the basal segment being longer than the others. They are clothed with fine hairs and short bristles. The tarsal claws are somewhat straight and have about five small teeth.

Abdomen is about 6.5 mm. long and has seven complete segments. In the non-gravid female it is somewhat dorso-ventrally compressed. In the gravid female it is fusiform, narrowed in front and behind. The tergites and sternites are clothed with short recumbent hairs. The pleural membrane is transparent. There is a pair of spiracles on each of the seven complete abdominal segments. The genitalia (Text-fig. 5) are partly telescoped within the seventh abdominal segment. The ovipositor, which is short, appears to be formed from the sternite of the eighth segment, which is divided into two setose concave plates situated one on each side of the genital aperture. The tergite of the segment is lacking. Concealed between the concave plates is a delicate irregular ring of chitin surrounding the gonopore. This may represent a very much reduced ninth segment. The anal segment, which projects slightly above the genital aperture, has a pair of setose lateral plates or paraprocts.

Male.

Length (without antennae) 8.8 mm.

Colour is somewhat darker than that of the female, the whole thorax being black. The femora and tibiae are reddish brown but the other segments of the legs are black.

The form and clothing of the antennae, head, palpi, thorax, wings and legs much the same as in the female.

Abdomen is about 6.5 mm. long and has eight complete segments. It is somewhat dorso-ventrally compressed. A small accessory sclerite is situated between the first and second sternites. The ninth segment has a tergite, which is emarginate posteriorly and produced downward on each side partially enclosing the genitalia. The ninth sternite is divided mesially into two parts, each of which gives rise posteriorly to a twisted hook-shaped gonapophysis (Text-fig. 6). If the tergite is removed the aedeagus is seen. It has a pair of rounded lobes, one on each side of the genital aperture. In front it is connected to two long curved apodemes, which extend into the eighth segment (Text-fig. 7). The anal segment has a small sternite and a pair of paraprocts. Each of the eight complete abdominal segments has a pair of spiracles.

Locality: Fern Tree, Mount Wellington, Tasmania. January, 1962.

Immature stages.

The *egg* is slightly ovoid and measures 0.34 x 0.29 mm. It has a brownish chorion.

First larval stage (Text-fig. 8) is about 1.25 mm. long. It has a well developed head, a thorax of three segments and an abdomen of nine. The head is brown and well chitinized. The rest of the body is soft and creamy white, the internal organs being visible through the transparent body wall.

The head (Text-figs. 9 and 10) is about 0.180 mm. long and 0.126 mm. wide at the antennae. It narrows slightly towards the posterior and the epicranium is emarginate behind. The frons appears to be fused with the lateral epicranial plates, which curve to the ventral side of the head. The lower edges of the plates almost meet in front behind the maxillae, but posteriorly the edges diverge and then converge again leaving between them an elongate pyriform space, where the chitin is thin and transparent. Each antenna has the form of an oval convex transparent membrane surrounded by a chitinous ring. Close below the ring is a small ocellus. On the dorsal side of the head between the antennae is a thick, strongly chitinized transverse bar, above which is a row of four sensory organs. Two other sensory organs are situated on the dorsal surface of the head, one on each side in line with the posterior edge of the antenna. The labrum (Text-fig. 11) is almost semicircular and is provided with three pairs of sensory organs. The mandibles (Text-fig 12) are large, well curved and powerful. The maxillae (Text-fig. 13) and palp are transparent leaf-like structures. The maxilla has two teeth on its inner margin. A circular sensory organ with four papillae is situated near the apex of the palp.

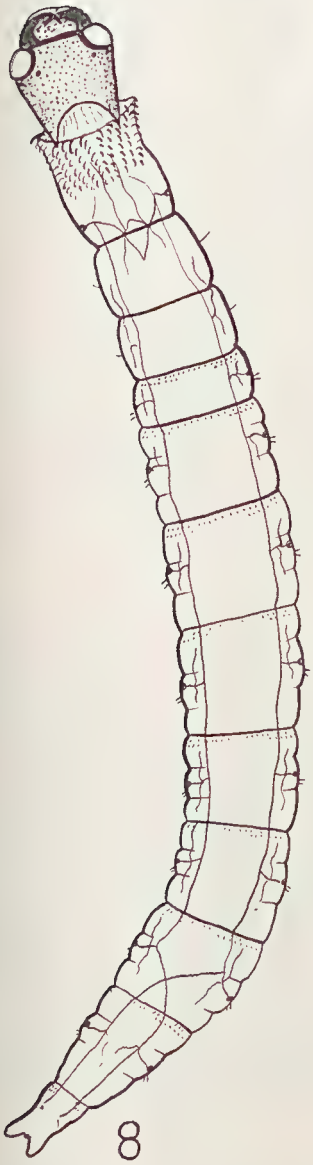
The front of the prothorax forms an introvert, which enables the head to be completely withdrawn. The introvert is armed with numerous hook-shaped spines arranged in longitudinal rows. There are about 10 rows above and 15 below. The longest rows have about twelve spines. The lateral and median rows are shorter than the others and have a smaller number of spines. In each row the spines decrease in size posteriorly and become more numerous. When the head is extended the spines point backwards, but when the head is withdrawn the spines are also withdrawn and then point forwards inside the introvert. A narow space on each side of the introvert is devoid of spines. A pair of spiracles open laterally in the posterior third of the prothorax.

On the ventral side at the front of the mesothorax and metathorax are further small hook-like spines arranged in short longitudinal rows, having about five spines in the longest rows. Spines are absent from the dorsal side of the two segments.

The abdomen tapers posteriorly. All the abdominal segments except the first and last are transversely wrinkled. The first seven possess a pair of spiracles. Close behind each spiracle are two small setulae. The main trunks of the tracheal system seen from the dorsal side are shown in Text-fig. 8. Round the anterior of each segment of the abdomen is a more or less complete double row of minute spinules. The last abdominal segment is divided posteriorly into two lobes.

Second larval stage (Text-fig. 14) is about 11.7 mm. long and 1.14 mm. in greatest width. However, when full-fed it may measure 17.1 mm. long and 2.0 mm. in greatest width. It has a head, three thoracic segments and nine abdominal segments. In general appearance it is vermiform and somewhat narrowed in front and behind. The colour is creamy white and the body-wall transparent.

The head (Text-fig. 15) is small and rounded, being about 0.57 mm. in diameter. The greater part of the cranial capsule is pale soft and transparent. Only the edges of the plates appear more or less strongly chitinized. The lateral epicranial plates curve ventrally, their lower edges converging behind the maxillary plates and strongly diverging posteriorly. The antenna has the form of a convex transparent membrane surrounded by a dark ring of chitin. A small ocellus lies close behind the antenna. The labrum (Text-figs. 16 and 17) is somewhat semicircular. On its dorsal surface are twelve sensory organs arranged in two groups of six. The anterior margin and part of the lower surface are furnished with a number of small pointed processes. Fan-shaped organs are absent but the ventral surface of the labrum has a median V-shaped structure and a pair of pointed lateral processes, which converge towards the median structure. The mandible (Text-fig. 18) is not lamelliform but strong and stout. Its outer margin forms a well rounded ventrolateral angle. The inner margin is armed at the apex with seven teeth (Text-fig. 19). Attached to the inner side is a prostheca having seven pointed processes. The maxilla (Text-fig. 20) is leaf-like and has twelve teeth along its inner margin. The palp is soft and membranous. It has a sensory organ in the middle



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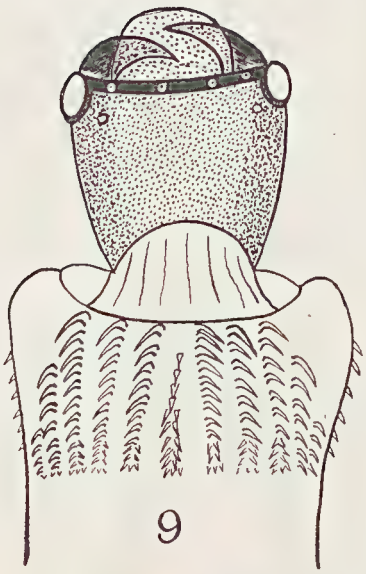

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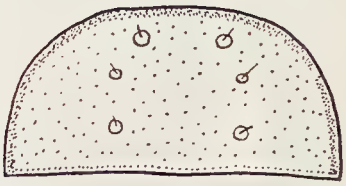

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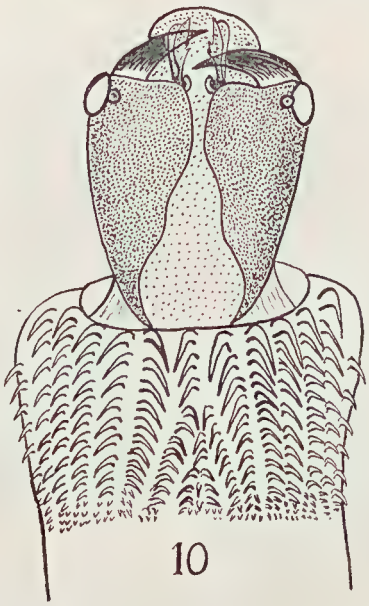

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Planarivora insignis sp. n.

First larval stage.

FIG. 8.—Larva from above showing main tracheal tubes.

FIG. 9.—Head and introvert from above.

FIG. 10.—Head and introvert from below.

FIG. 11.—Labrum from above.

FIG. 12.—Mandible.

FIG. 13.—Maxilla and palp.

of its distal half. The maxillary plate is somewhat triangular. The hypopharynx (Text-fig. 21) consists of two vertical rods and a pair of horn-like horizontal processes. The vertical rods meet ventrally in a U-shaped bend round the opening of the salivary duct. Below the bend is a rudimentary plate representing the labium.

Between the head and prothorax is a short introvert, which turns inward when the head is withdrawn. This region is furnished with minute spinules, which are quite unlike the large hook-shaped spines of the first stage larva. Two spiracles are situated, one on each side, in the posterior half of the prothorax. On the ventral side of the three thoracic segments the imaginal disks of the three pairs of legs may be seen. All the thoracic and abdominal segments have transverse rows of minute spinules on the anterior margin, the spinules being more numerous ventrally than dorsally.

The second to the eighth abdominal segments have a number of transverse wrinkles or annuli. A pair of spiracles is present on each of the abdominal segments except the last. The body of the larva appears to be quite devoid of setae. The last segment ends in a pair of lobes, one on each side of the anus.

The larva has a large crop and a pair of gastric caeca. Four Malpighian tubules arise at the posterior end of the midgut. The salivary glands are long, tubular and convoluted. The tracheal system is peripneustic.

This second larval stage of *Planarivora insignis* has some features in common with the larva of *Ceroplatus lineatus* Fabricius described by Madwar (1937). The form of the antennae, maxillae, hypopharynx and labium is much the same in the two species. They also agree in having a body that is free from hairs. They differ, however, in the shape of the head, the structure of the mandibles and labrum and in the segmentation of the body. Moreover, the larva of *Ceroplatus lineatus* is said to be apneustic and free-living, whilst that of *Planarivora insignis* is peripneustic and parasitic.

The *pupa* (Text-fig. 22) measures 7.14 mm. long. The head is 0.97 mm. wide. The thorax and abdomen both 1.71 mm. wide. The antennae curve back over the eyes and reach the mesothorax. The wings and legs extend along the ventral surface of the body. The first pair of legs and the wings reach the third abdominal segment, the second pair of legs the fifth segment and the third pair of legs the sixth segment. On the first seven abdominal segments are two small conical projections, one on each side, marking the position of the tracheal spiracles. The sternite of the ninth segment has a deep median cleft on the posterior margin.

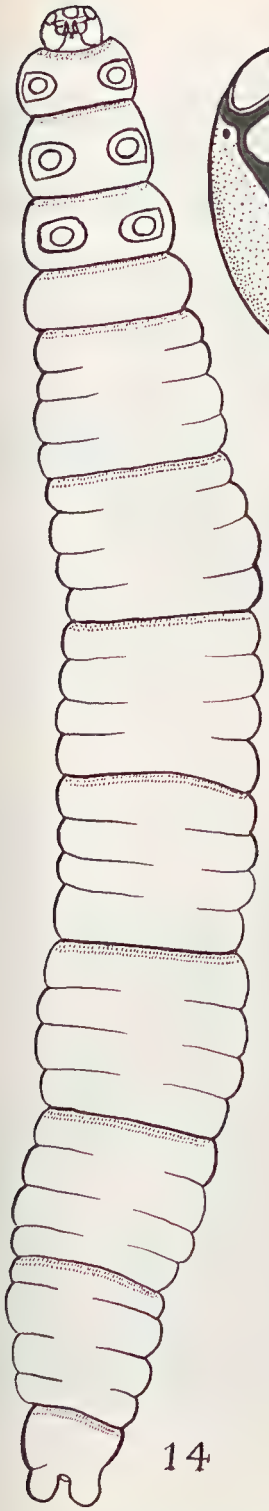
Biology of *Planarivora insignis*.

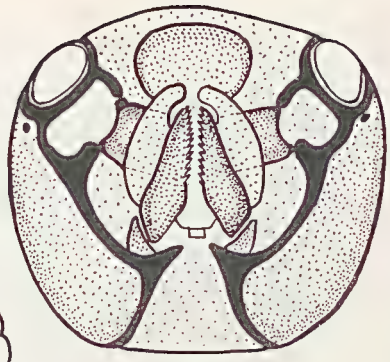
Adults first appear about the middle of January. When the female emerges from the pupa the whole of her abdomen is already distended with eggs, which are visible through the transparent pleural membrane. In the case of one specimen that was dissected 683 eggs were counted.

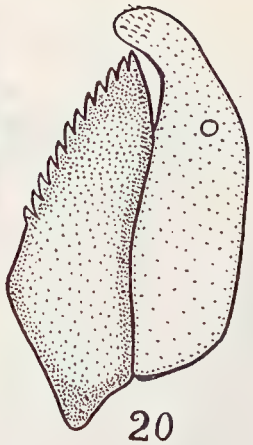
In vivaria where non-infected specimens of *Geoplana tasmaniana* (Pl. 1, fig. 1) were kept together with adults of *Planarivora insignis*, it was found that the females of the mycetophilid laid their eggs about two or three days after emerging from the pupa. The eggs were deposited singly and scattered about near the moss under which the land planarians were concealed. Unfortunately the eggs failed to develop and hence the exact duration of the incubation period is not known. However, under natural conditions at Fern Tree, Mount Wellington, land planarians were found to be infected with the first stage larva towards the end of April. At the beginning of May larvae of only 1.25-2.28 mm. length were collected by dissection from specimens of *Geoplana tasmaniana*. One such larva removed on 1st May, 1962, was washed free from the copious slime of the planarian and then placed on the dorsal surface of another non-infected specimen of *Geoplana tasmaniana*. The larva began to penetrate the planarian immediately, using its powerful mandibles and hook-like spines to pierce the body-wall. In about eight minutes it had reached the interior of its host. The planarian reacted by ceasing to creep, flattening the body and then raising the lateral margins so that the dorsal surface was concave. It remained thus for about 20 minutes, making only feeble movements with its anterior end. It then began to move about normally. No wound was visible where the small larva had entered.

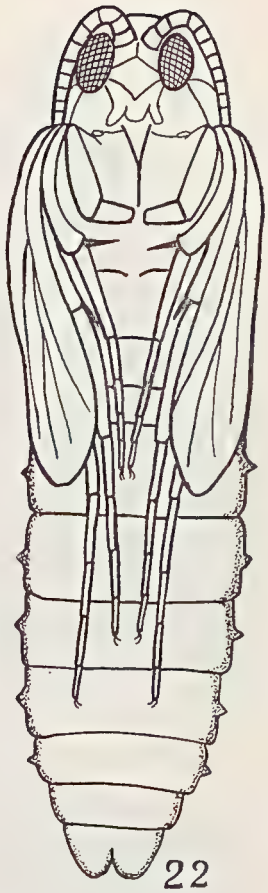
During the year 1962 one hundred and eighteen specimens of *Geoplana tasmaniana* were collected at Fern Tree. Of these 33 were found to be infected with the larva of *Planarivora insignis*. In 31 of the infected specimens only a single larva was present in each, but in the remaining two planarians two larvae occurred in each. Before they were preserved nearly all the larvae were measured and it was found that during the greater part of the year, April to November, the first stage larva grows very slowly, reaching a maximum length of about 4.0 mm. During this time it does not seem to cause much harm to its host. If the planarian is not too heavily pigmented, the larva may be seen through the body wall. Towards the end of the year there is apparently very rapid growth (see Table I). Thus six larvae collected in December measured from 6.9 mm. to 9.0 mm. in length. They were all second stage larvae. In each case the exuviae of the corresponding first stage larva were found within the body of the planarian. The head capsules of the exuviae measured in diameter 132, 132, 133, 126, 135 and 129 micra respectively.

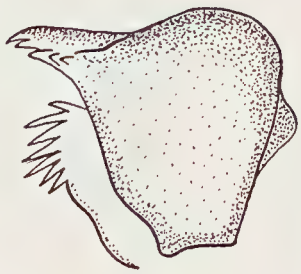
The second stage larva feeds voraciously and infected planarians are often found with small wounds in the body-wall. These wounds may serve to allow the rapidly growing larva more ready access to air, or they may be merely lesions caused by its feeding. The rapid destruction of its internal organs soon results in the planarian becoming less active and finally ceasing to move about. The larva now bites its way out of its host (Pl. 1, figs. 2 and 3). It then continues to feed until little of the planarian remains.

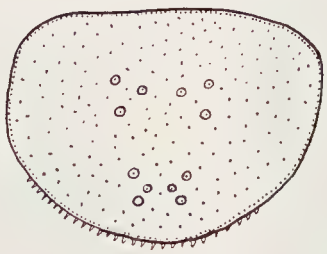


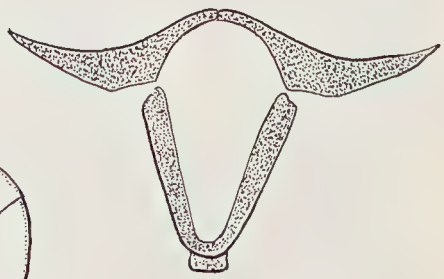


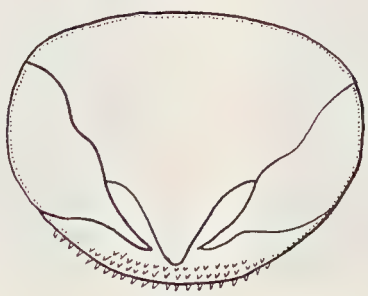












Planarivora insignis sp. n.

Second larval stage and pupa.

FIG. 14.—Larva from below.
FIG. 15.—Head of larva from below.
FIG. 16.—Labrum of larva from above.
FIG. 17.—Labrum of larva from below.
FIG. 18.—Mandible and prostheca of larva.
FIG. 19.—Apex of mandible of larva.
FIG. 20.—Maxilla and palp of larva.
FIG. 21.—Hypopharynx and labium of larva from below.
FIG. 22.—Pupa from below.

TABLE 1.

Number of specimens of *Geoplana tasmaniana* examined during the year 1962 and the number and size of the larvae of *Planarivora insignis* found.

Month	*Geoplana tasmaniana* Examined	Infected	*Planarivora insignis* Larvae found	Lengths (mm.)
Jan. ..	....	....	....	....
Feb. ..	16	0	....	....
Mar. ..	8	0	....	....
Apr. .	. ..	....	.. .	....
May ..	39	8	8	1.25-3.0
Jun. ..	3	2	2	not recorded.
July ..	8	4	6	1.90-2.70
Aug. ..	....	....	....	....
Sep. ..	14	5	5	2.85-3.14
Oct. ..	11	7	7	2.85-3.30
Nov. ..	8	1	1	4.0
Dec. ..	11	6	6	6.9 -9.0
Total	118	33	35	

When full-fed the larva creeps into a crevice under a moss-covered stone or in a rotten log and there spins a frail mesh-work of threads (Pl. 1, fig. 4). A specimen kept under observation in the laboratory commenced spinning on 3rd January, 1962 and finished on 8th January, 1962. The threads are spun from the opening of the salivary duct and the larva raises the anterior part of its body, moving its head from side to side and up and down as it searches for points to which the threads may be attached. When spinning, some of the threads are fixed to the larva's own body in order to suspend it. Many of the threads support clear liquid droplets. Tests show that the droplets contain oxalic acid.

A few hours after completing the frail mesh-work of threads which serves as a delicate cocoon, the larva defaecates and at the same time expels its Malpighian tubules. It then undergoes ecdysis disclosing the pupa. The larval exuviae remain adhering to the posterior end of the pupa. Pupation lasts about eight days. When the imago emerges from the pupal exuviae, it does not immediately move away. Usually it rests by the cast off skin in the mesh-work of threads for two or three days before taking flight.

In addition to parasitising *Geoplana tasmaniana* (Darwin), the larvae of *Planarivora insignis* are also sometimes found in *Geoplana mortoni* Dendy and *Geoplana diemenensis* Dendy, which occur at the same locality.

ACKNOWLEDGEMENTS

I am indebted to the Librarian of the University of Tasmania for obtaining literature not available locally. My thanks are also due to Dr. J. L. Hickman for assistance in collecting land planarians at Fern Tree.

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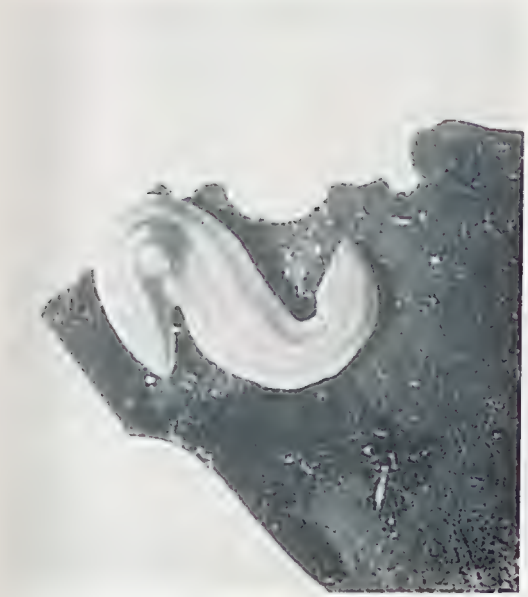

1

2

3

4

Plate 1.—

Fig. 1.—*Geoplana tasmaniana* resting on a fallen leaf. X 2.

Fig. 2.—*Geoplana tasmaniana* with two lesions in the dorsal surface through which the larva of *Planarivora insignis* is emerging. X 2.

Fig. 3.—*Geoplana tasmaniana* with the larva of *Planarivora insignis* fully emerged and feeding on the body of its host. X 2.

Fig 4.—The larva of *Planarivora insignis* spinning a frail mesh-work of threads in which to pupate. X 1.

F.P.S.

Papers and Proceedings of the Royal Society of Tasmania, Volume 99.

SOME OBSERVATIONS ON THE DOLERITE INTRUSION AND ASSOCIATED STRUCTURES AT GOLDEN VALLEY, NORTHERN TASMANIA

By

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(With three text figures.)

ABSTRACT

Investigation of an intrusion of Middle Jurassic dolerite at Golden Valley showed the structure to be more complex than previously described. The intrusion appears to be located on a thrust which has brought Precambrian quartzite and schist up against Ordovician conglomerate. The magnitude of the movement is not easily determined due to uncertainties concerning the thickness of the Cambrian sequence in this vicinity. The fault is considered to be a Lower Palaeozoic feature which has controlled the site of intrusion of the dolerite, possibly with concomitant Jurassic movement. The dolerite intrusion also appears to be related to a high in the Precambrian basement and possibly a Cambrian volcanic centre.

THE GOLDEN VALLEY CONE SHEET

The Golden Valley cone sheet structure (Carey, 1958) was proposed following field mapping by Wells (1957). Wells' map shows a plug of Ordovician Owen Conglomerate occupying the vent of the dolerite cone. Carey postulated that a considerable downthrow was needed to bring the conglomerate into its present position in the vent. Cambrian rocks oucrop outside part of the cone and the presence of the conglomerate within the vent is anomalous on dilational considerations. For these reasons the structure was investigated more closely.

THE ROCKS WITHIN THE DOLERITE CONE

The present investigation showed that the core of the cone sheet is more complex than previously described (figures 1 & 2). The core outcrops as a small hill. The top of this hill consists of Ordovician conglomerate lying against Precambrian quartzite and schist to the west and south. The rock underlying the conglomerate is largely obscured by scree from above but some slightly sheared and indurated fine sandstone was observed. The obscuring scree deposits consist of a superficial layer, one to two feet thick, overlying more consolidated scree in which the conglomerate fragments are embedded in a clay matrix. This matrix is presumably derived from the underlying sandstone. A thin section of the sandstone showed it to be very similar to the subgreywacke described by Wells from the Archer Formation of Cambrian age. Pieces of this rock were also observed immediately underneath the ridge of Ordovician conglomerate outcropping to the south-west outside the dolerite cone.

The Precambrian rocks consist of massive, laminated, and schistose quartzites; quartz-mica schists; and schists. The schists are strongly foliated and are mostly orange-grey muscovite-quartz-biotite schists. Some lustrous green chloritic schists were also observed. The structural relationships of these rocks are somewhat difficult to discern due to their shattered nature, but they appear to strike at approximately 300 degrees and dip fairly steeply to the north-east.

The Fabric Evolution of the Schists

An orientated specimen of schist was studied in thin section to determine the fabric evolution as outlined by Spry (1963b). The specimen is slightly weathered and consists of muscovite 40%, quartz 35%, biotite 20%, and garnet 5% with zircon, epidote, rutile, and andalusite ? as accessories.

The schist is complex in structure and shows three foliations. The major schistosity S2 strikes along the bedding but dips about 60 degrees to the south-west. It consists of alternate bands of mica and quartz plus mica. The bands are strongly crumpled and in places strongly disrupted forming a fracture cleavage S3. Remnants of an older foliation S1 can just be discerned as thin tightly folded bands of mica between S2. S1 and S3 parallel each other, dip at about 60 degrees to the north-east and are probably parallel to the bedding So.

Muscovite occurs as moderately coarse flakes bent around the folds of S1 and S2. It also occurs as randomly orientated flakes that are post-tectonic to these foliations. Sericite has replaced the muscovite in places along S2. Its development was either syntectonic with, or post-tectonic to, S3 as it also occurs along this foliation. Biotite forms large, dark brown, ragged and bent flakes syntectonic with S2. A few random flakes are post-tectonic to S2, and some of the biotite has been rotated into parallelism with S3.

Garnet occurs as porphyroblasts up to 3 mms. in diameter. The crystals generally contain numerous inclusions of quartz and tend to be skeletal. The main foliation wraps around the garnet which is thus pretectonic to S2. Snowball structure in some of the garnet suggests it is syntectonic with S1. The garnet, and in places the surrounding matrix,

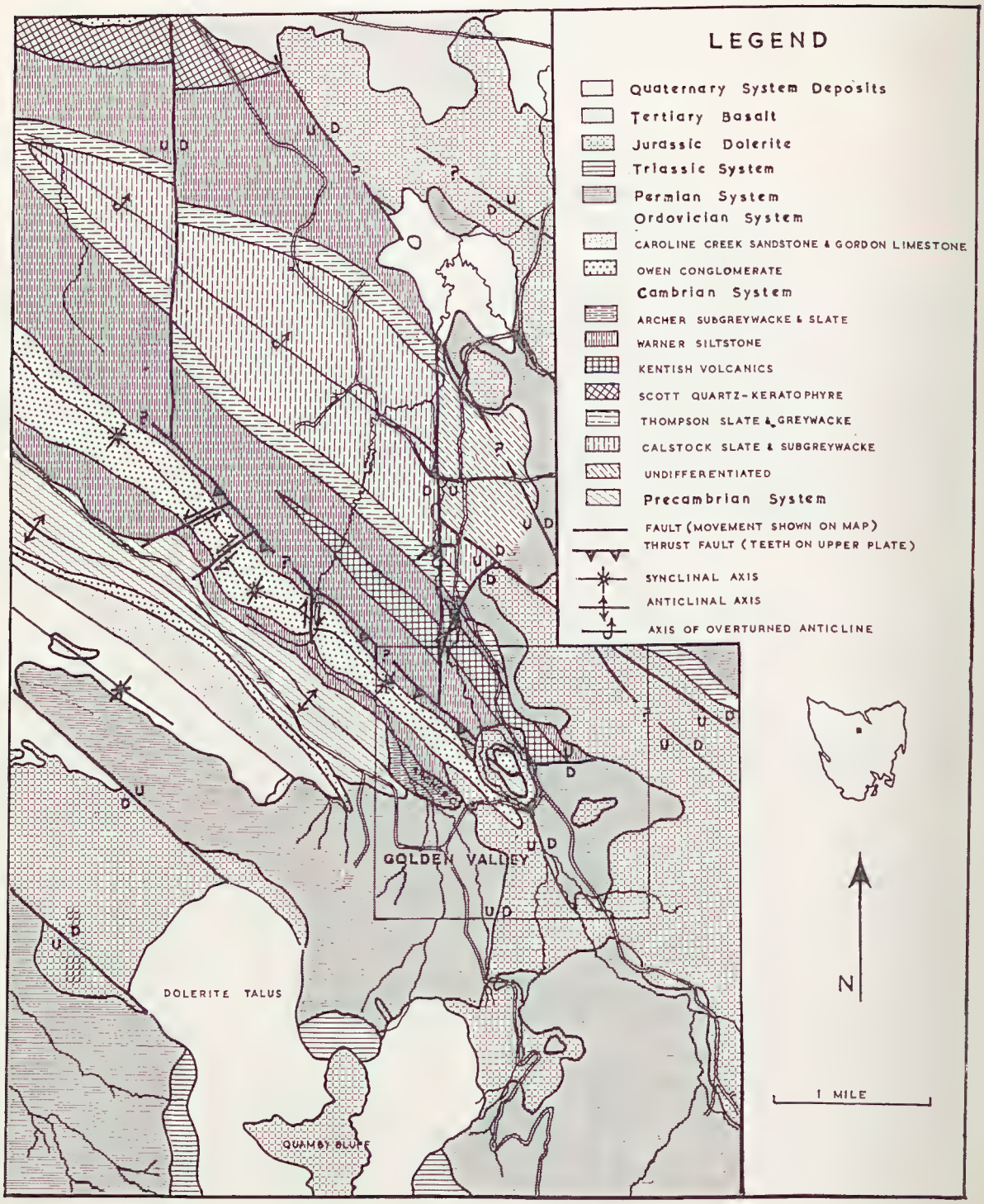

Fig. 1.—Geological map of the Golden Valley District based on Wells (1957) and Carey (1958) with amendments.

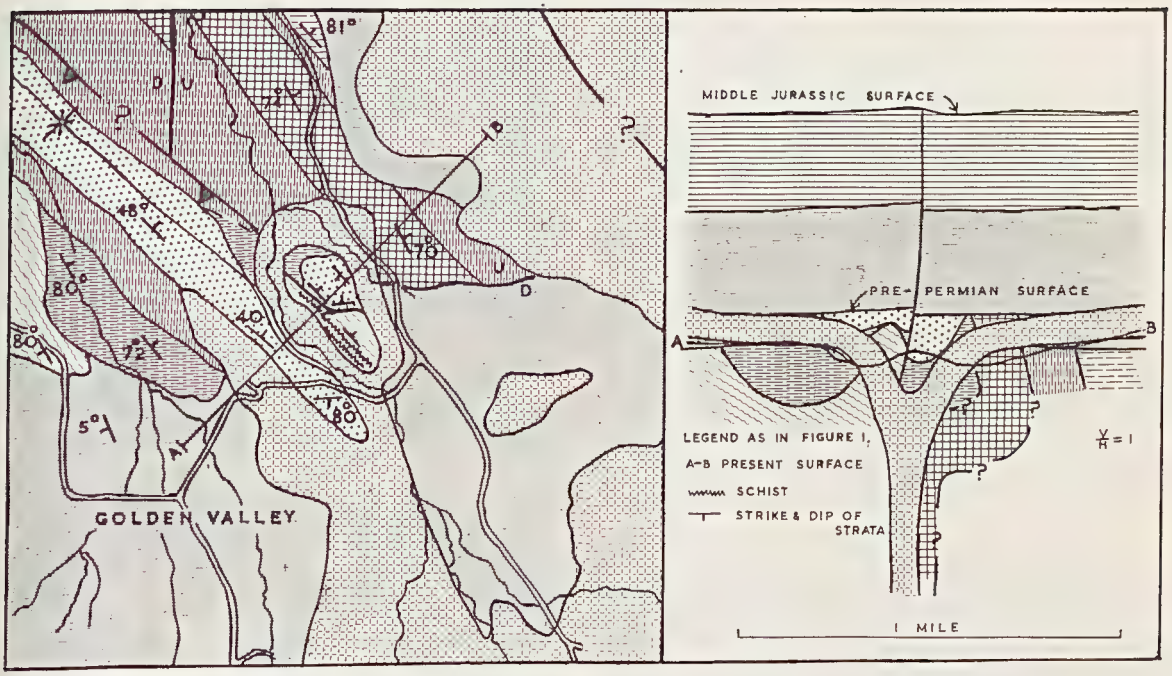

Fig. 2.—Detail of the structure at Golden Valley, with section showing a possible reconstruction.

has been extensively altered to a mixture of sericite and limonite, the severest alteration occurring along the numerous fractures in the garnet. Rare porphyroblasts of a mineral containing quartz inclusions and which is completely altered to sericite, were also observed. The mineral crystallised pretectonically to S2 and may have been albite, or possibly andalusite as a few minute crystals of chiastolite were observed as inclusions in S2.

The rock is also cut by quartz veins that cut across all the foliations, although some veins are strongly plicated.

The fabric of the schist is thus consistent with those of the Precambrian schists that have been described from Tasmania (Spry, 1963a, 1963b, Gee, 1963). S1 and S2 were imposed during two periods of deformation, F1 and F2, probably associated with Precambrian regional metamorphism. Later deformation F3, which produced the strong folding of S2, the fracture cleavage S3, and the gash quartz veins, probably consists mainly of post-Precambrian movements. These relationships are shown in figure 3.

THE STRUCTURE WITHIN THE DOLERITE CONE

The Precambrian rocks appear to have been brought up against the Palaeozoic rocks along a steep thrust. The faulted nature of this contact is most apparent where the Precambrian rocks lie against the Archer Formation. Here the contact is marked by strong shearing, with brecciation and contortion of the Precambrian quartzites. The contact between the Ordovician conglomerate and the Precambrian rocks may represent an uncomformity with the conglomerate lapping up against a fault scarp of Precambrian rock. However the presence of brecciated quartzites and the development of gossan on the schists in places along the contact suggest it is a fault. The Ordovician conglomerate, then, appears to be a small remnant of a synclinal keel rising rapidly to the north-east with updragging to the south-west against the fault.

The magnitude of the movement on this fault is difficult to determine. The Cambrian sequence appears to have been faulted out but the thickness of the Cambrian beds here is not known with certainty. If the interpretation of the structure shown by Wells in his cross-section across the Cambrian depositional basin is correct, then there has been considerable vertical movement of the order of thousands of feet. The presence of the Precambrian rocks, however, indicates that there is a high in the Precambrian basement here, even after allowing for dilation by the dolerite cone. Supporting evidence for this interpretation involves the nature of the Ordovician conglomerate and the presence and distribution of the Archer formation. This evidence will be discussed more fully further on. Thus the thickness of the Cambrian sequence here need not be very great and, indeed, Ordovician conglomerate may have rested directly on the Precambrian high. This case does not necessarily call for a substantial upthrow along the fault.

The line of thrusting probably continues outside the cone sheet linking up the faults mapped by Wells to the north-west. The lateral movements on the small faults cutting the syncline of Ordovician conglomerate to the north-west of Archers Creek are certainly more understandable if they are linked to a line of upthrusting from the south-west. It is difficult, however, to trace this fault in the lithologically uniform Cambrian beds.

THE TECTONIC HISTORY OF THE DOLERITE INTRUSION AND ASSOCIATED STRUCTURES

The line of thrusting associated with the dolerite intrusion at Golden Valley marks the margin of a Cambrian trough. The Cambrian sequence is considerably thicker on the downthrown side of the fault than on the upthrown side. Further, all the formations that occur on the downthrown side below the Warner Formation are missing from the sequence on the upthrown side. It is likely, then, that this was a fault controlled trough such as occurs in the Devonport area (Burns, 1962), and that the line of thrusting was initially a Cambrian structure.

It is of interest that the Kentish Volcanics and the fault line converge toward a meeting point just to the east of the dolerite cone. The volcanics increase in thickness towards this meeting point. Thus there are indications of a Cambrian volcanic centre situated near the fault line. It was presumably a submarine vent and pillow structure can be observed in the outcrop of spilite due east of the dolerite cone. Fragments of spilite identical to that of the Kentish Volcanics were found by Wells in the underlying Thompson Formation. One possible explanation is that these represent earlier reworked spilites erupted from this centre.

The trend of the line of thrusting and that of the fold axis of the large overturned anticline in the Cambrian beds on the downthrown side of the fault are approximately parallel. This suggests the anticlinal folding possibly was controlled by compression against the fault wall of the depositional trough. The fold is cut by two large north-south trending faults. Wells considered this folding and faulting to be associated with the Jukesian Movement of the Tyennan Orogeny, presumably because the faults did not appear to cut the Ordovician rocks. However, the intervention of a connecting thrust on which there appears to have been post-Ordovician movement admits the possibility that they may be Tabberabberan structures. Whether any of the folding and associated faulting can be attributed to the Jukesian movement is a debatable point. Certainly if the Ordovician beds are unfolded a residual anticlinal structure remains in the Cambrian beds. This may not be due to Jukesian movements as there is likelihood of the Cambrian-Ordovician interface acting as a decollement surface during Tabberabberan folding, thus producing "pseudo-unconformities" (Solomon, 1960). The line of thrusting may represent such a decollement.

Dolerite magma appears to have intruded up the fault line in the Middle Jurassic as a steep sided cone (figure 2). The ascending dolerite seems to have been deflected laterally on striking the synclinal keel of massive Ordovician Conglomerate, before spreading out up into the Permo-Triassic sediments. Isostrat analysis of the dolerite structure (Carey, 1958) indicates the whole of the dolerite cone was elongated in a north-westerly direction along the trend of the fault line. The isostrat analysis also indicates that the intrusion was accompanied by concomitant radial faulting. Although the post-Ordovician thrusting may be a Tabberabberan event, there is no conclusive evidence for this and some or all of the thrusting may have been concomitant with the dolerite intrusion. It is unlikely there was any large Jurassic movement involved as there is no marked discrepancy in the heights of the base of the Permian System across the thrust.

The trends of the main Tertiary faults within the area are similar to that of the line of thrusting. However, the dolerite margins of the cone show no marked dislocations and any Tertiary movement along the fault could not have been very substantial.

SUMMARY AND DISCUSSION

The dolerite intrusion at Golden Valley appears to be closely related to a north-west trending line of thrusting, a high in the Precambrian basement, and possibly a Cambrian volcanic centre.

The age of the line of faulting cannot be conclusively determined. There is some evidence that it became active at the time of deposition of the Cambrian beds and that there were subsequent movements. The coarse greywacke breccias noted by Wells at the top of the Archer Formation suggest possible late Cambrian movements. Post-Ordovician thrusting along this line may have

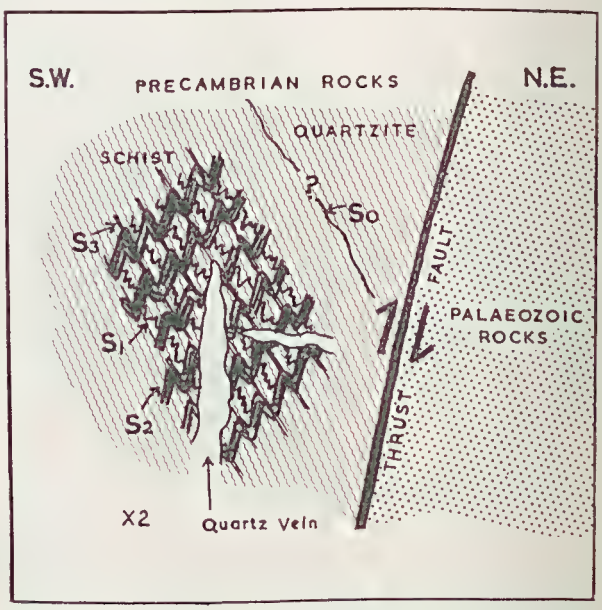

Fig. 3.—Diagrammatic section showing the relationship of the foliations in the Precambrian schists.

taken place during the Tabberabberan Orogeny and/or concomitantly with the dolerite intrusion in the Middle Jurassic. There may also have been small movement during the Tertiary epeiorogeny. The fault has brought the Precambrian basement up against Ordovician conglomerate, but the amount of movement is difficult to estimate. The post-Ordovician throw on the fault is probably not more than a few hundred feet. An analysis of the fabric evolution of a schist from the upthrown Precambrian basement showed the Precambrian foliations to be strongly crumpled and disrupted with the development of a fracture cleavage. This later deformation was probably imposed by post-Precambrian movements and is consistent with shearing associated with the thrusting from the south-west (figure 3).

The outcrop of Precambrian rocks within the dolerite intrusion is probably part of a basement high. This high may have resulted from uplift in late Cambrian times, the uplift being reflected in the subgreywackes and greywacke breccias of the Archer Formation. The restricted distribution of the Archer Formation around this vicinity suggests the uplift was somewhat localised and may have related to the Cambrian volcanic centre. The nature of the Ordovician conglomerate lying against the Precambrian rocks within the dolerite also hints at the existence of a nearby Precambrian high. Wells describes the Ordovician conglomerates of the district as being composed of pebbles averaging 5 cm. in diameter with a maximum observed size of 16 cm. However the conglomerate at the locality under discussion differs in containing fragments up to boulder size. The largest fragment observed by the writer was about 100 x 90 x 75 cm. in dimensions.

Very little is known concerning the control of intrusion sites of the Jurassic dolerite feeders in Tasmania. Some of the intrusions are located on concomitant Jurassic faults. Examples include the feeder-dyke intruded along the Tiers Fault (Carey, 1958) and possible cone sheet structures at Huonville (Carey, 1958) and Patersonia (Longman, et alii, 1964), both of which are bisected by a concomitant fracture. These faults may represent renewed movements along Pre-Jurassic structures in the underlying basement. The intrusion at Golden Valley is significant in this regard in that it appears to be located on a Palaeozoic fault line. Domal structure as a control over the intrusion sites of cone sheet structures in Tasmania has also been suggested (Sutherland, 1964). The Golden Valley intrusion is also significant in this respect as it appears to have intruded at a basement high. However, although Carey (1958) has presented good evidence for a cone sheet structure at Golden Valley, this structure has not yet been established conclusively. It is hoped that criteria necessary for recognising cone sheet structures in Tasmania will be established at a future time and the possible cone sheet structures examined in the light of these criteria.

ACKNOWLEDGEMENTS

The writer would like to acknowledge the helpful criticisms of both Dr. A. H. Spry and Mr. M. R. Banks, Geology Department, University of Tasmania, who kindly read the manuscript. Specimens and thin sections of the rocks discussed in the paper are held in the collections of the Queen Victoria Museum.

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ADDENDUM

Since the above observations were written, the author, accompanied by Mr. N. Cane, Department of Geography, Australian National University, has critically examined some of the dolerite outcrops mapped by Wells in the Golden Valley area. The examination showed that some of the dolerite mapped as bed rock is probably not *in situ*.

Wells has mapped a tongue of intrusive dolerite crossing the Quamby Brook Highway, one third of a mile from the turn-off from Golden Valley. Numerous fragments of dolerite, including some large blocks, are present here, but recent clearing on the north side of the road has revealed pieces of friable sandstone in the surface float and a sandy soil unlike that normally developed on dolerite. Large blocks of the sandstone, up to ten feet high, were observed associated with dolerite float a few hundred yards to the south of the road. The sandstone closely resembles that of the Triassic System or the Liffey Formation and is out of place in its present position. The nature of the dolerite exposed in the road cutting a few hundred yards down the road towards Quamby Brook also strongly suggests transported material. The most obvious source of the material is Quamby Bluff and there are several possibilities as to the mode of transport. There is little evidence that this locality was glaciated during the Pleistocene and transport of the large blocks of dolerite and sandstone by a glacier is considered unlikely. The elevation of these blocks (approximately 1,200 feet above sea-level) is possibly too low for transport by periglacial solifluction in the late Pleistocene. It is thought the deposit is most likely a remnant of an old talus. Post-Pleistocene gravity rolling from Quamby Bluff probably can be discounted due to the presence of a small intervening valley. Many of the dolerite fragments show ironstone crusts a few mm. thick with an interior of fresh rock. This suggests the deposit is older than the last Pleistocene glaciation in Tasmania, but perhaps not very much older.

Thus, most of the dolerite on the north-eastern slope of Quamby Bluff down into Quamby Brook Valley may be transported material derived from the sills capping Quamby Bluff and Cluan Tier, rather than intrusive bed-rock. Where the dolerite was examined along the Lake Highway on the slopes of Quamby Bluff, from between one and two miles from Golden Valley, there seemed no reason to suppose it could not represent solifluction deposits. However, two localities were observed where the dolerite convincingly appeared to be *in situ*, namely where it crosses the Lake Highway a little less than a mile from Golden Valley and in the western part of the annulus of dolerite, two thirds of a mile north-east of Golden Valley. Careful discriminatory mapping of the dolerite is needed before the extent and form of the dolerite intrusion in this area can be properly gauged. Geophysical methods appear to be the best means of confirming or disproving the existence of an intrusive dolerite cone centred in Quamby Brook.

Papers and Proceedings of the Royal Society of Tasmania, Volume 99.

OBSERVATIONS ON THE GEOMORPHOLOGY OF A COASTAL CAVE NEAR WYNYARD, TASMANIA

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ABSTRACT

A seaward facing cave is noted on the coast immediately to the east of the Sisters' Creek beach; and the presence of a cemented water rolled conglomerate adhering to parts of the ceiling suggests an old sea level, at a height of the order of 100 feet above the present sea level.

DESCRIPTION

During an archaeological survey carried out under the auspices of the Australian Institute of Aboriginal Studies, and the Department of Anthropology at the University of Sydney in the summer of 1963-64, an investigation was made into the caves to be found in the precambrian quartzites (Cave quartzite of Spry, 1957) of the Sisters' Hills on the coast about six miles northwest of Wynyard.

One of these caves is situated in the side of a high seaward facing cliff, about half an hour's walking distance across bush and rocky foreshore in an easterly direction from the end of the vehicle track at the eastern end of the Sisters' Creek beach. The entrance to this cave is about 30 feet high and 65 feet wide, and it faces out to sea in a northeasterly direction, the surface of the floor deposit being about 60 or 70 feet above sea level. When one stands on the talus at the mouth, and looks at the cave, one can see that it consists of two slits, the westerly one being 40 feet high and 16 feet broad, slopes down to the left at an angle of about 60 degrees; and the easterly one is 25 feet high and 20 feet broad at the widest part, and slopes down to the right. These are separated by a section of the folded bed-rock, 15 to 20 feet in thickness.

The roof of the easterly slit cave is smooth and fairly level, and adhering to it can be seen patches of a cemented conglomerate. This conglomerate is probably that named the Sisters Conglomerate by Spry (1957) and consists of tightly packed, water rolled stones in a sand matrix, some of these pebbles being completely rounded, and up to about a foot in diameter. Inspection shows that this conglomerate is cemented onto the ceiling of the cave, the junction being quite distinct, and it is very probable that these are the remains of a much more extensive deposit, the floor beneath being littered with chunks of cemented pebbles that have fallen off. The conglomerate had been laid down after the formation of the cave, and as there is no possibility of deposition by streams, I would suggest a marine origin. Such a theory is strengthened when one examines the back end of the cave, about 60 feet in from the entrance. Here the protruberances of the bedrock are rounded and smoothed by water action, with extensive remains of the cemented conglomerate having been injected into and against the hollows and corners.

The height of the outer edge of the upper lip of this cave is 101 plus or minus 4 feet above mean sea level, and the conglomerate attached to the ceiling extends from a height of 95 feet to 90 feet. The height of the corner where the ceiling meets the back wall of the cave is 90 feet and the conglomerate extends a few feet below this. I would suggest that both caves were formed by marine action, and that the remains of an old cemented raised beach can been seen in the easterly one. These phenomena might be associated with a sea level 90 to 100 feet above the present level, though the dangers in deducing the height of an ancient shore line from pebble deposits must always be borne in mind. (Zeuner, 1959, p. 282).

Johnston (1888) records "Helicidae Sandstone", which Jennings (1959), calls aeolianite, at a height of about 100 feet above sea level, on Mt Chappel Island in the Furneaux Group. Lewis (1935) correlated these deposits with his "Pre-Malannan" gravels in the Derwent Valley, but his scheme must be rejected following the criticisms of Jennings and Banks (1958). Edwards (1941) makes the suggestion of possible river terrace remains in the Mersey and Forth rivers, indicating a strand line at about 100 feet above sea level. The best documented evidence is that of Jennings (1959) where he records boulder beds of water rolled pebbles in the open cut of the Grassy Creek scheelite mine. These beds have been noticed at various heights between 90 feet and 150 feet above sea level, and Jennings postulates their association with a high sea stand at 120 feet to 150 feet, although correlation with a succession of strand lines at other heights of that general order is also considered. Elsewhere in Tasmania, Hills (1914) reports a deposit of rounded boulders and shingle indicating a raised beach at a height of almost 100 feet above sea level, on the south side of the base of Point Hibbs. An eustatic sea level rise of the order of 100 feet has been recorded in many places all over the world, and this is correlated by Zeuner (1959) to his "Tyrrhenian" phase, which is generally assigned to the Mindel/Riss Interglacial period. Further it is possible that the Sisters' Creek caves and the Rocky Cape caves were formed during the same episode. They are similar in general shape, the bedrock in both cases is the Cave Quartzite, and they are situated within six miles of each other. Gill and Banks (1956),

and Gill (1959) assign a correlation to a 70 foot sea level, but doubt has been expressed by Jennings (1959).

In front of the Sisters' Creek cave is a large talus of hillwash which comes in from the outside slope above, and to the immediate west. This deposit has been cemented together, and consists of angular fragments of rock and soil. The front part of this talus is eroding away, and this leaves a face against the bedrock at the eastern end, which is about 15 feet deep. An examination of the top surface and the eroded face of this hillwash did not reveal any cultural material embedded in it. The floor of the western cave is behind this hillwash, about six feet below it, and it is very damp, being subject to flooding. The deposit is sandy and ravages of fossickers have upturned some shells and bones, attesting to at least some occupation by the aborigines in recent times.

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THE PRECAMBRIAN ROCKS OF TASMANIA, PART VII

NOTES ON THE PETROLOGY OF SOME ROCKS FROM THE PORT DAVEY-BATHURST HARBOUR AREA

By

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(With two plates and two text figures.)

ABSTRACT

Petrological examination suggests that the rocks of the Port Davey-Bathurst Harbour area may be divided into two main groups: the regionally metamorphosed schists, quartzites, phyllites and amphibolites which are probably older Precambrian, and the essentially unmetamorphosed sediments which are probably younger Precambrian. The latter can be divided into three main types; subgreywacke sandstones and slates (Ila Bay, Bramble Cove and north eastern Bathurst Harbour), greywacke sandstones, slates and conglomerates (Joe Page Bay) and orthoconglomerates and quartzites (Mts. Rugby, Berry, &c.).

INTRODUCTION

The geology of the remote south-western corner of Tasmania is complex and observations by Twelvetrees (1906, 1908, 1909), Baker (1957), Stefanski (1957), and Taylor (1959) have left major problems of structure and stratigraphy unanswered. Jennings (1960) summarized the information available and made suggestions as to possible stratigraphic relations as a basis for further work. Investigation of Precambrian rocks in various parts of Tasmania (Spry 1962a, 1962b, 1963a, 1963b) has shown that a study of the structural petrology of these rocks is a useful guide to the stratigraphy although use of the degree of deformation and tectonic style to subdivide the rocks of an area is by no means infallible (Spry 1963a). The following notes are based on field work (W.E.B. and A.S.) and petrology (A.S.). This work is generally in agreement with that of Jennings (1960), but like it, is only intended to be an aid to detailed field investigations in the future.

Despite the fact that the stratigraphy and structure of this area is almost completely unknown, no less than thirty-five stratigraphic terms have been used in a formal sense (Stefanski 1957, Baker 1957, Taylor 1959). With the possible exception of Jennings' (1960) terms, few of the formal names are used according to the Australian Code of Stratigraphic Nomenclature and at present it is practically impossible to understand what some terms mean. Formations and groups have been named without reference to type areas, the same rock is given different names of different authors (or even by the same author), unconformities or conformable successions are postulated with no supporting evidence, and the same stratigraphic name is used by different authors to apply to different rocks.

No formal stratigraphic terms will be used in this paper and it seems that, until formal stratigraphic terms can be used in an accurate, understandable manner, the stratigraphic names for this area may have to be abandoned.

PRINCIPLES

The rocks are divided into a number of lithological assemblages using the amount of metamorphism and deformation as criteria following Spry (1962a) because the structural and stratigraphic relations are not yet clear from field studies. The low to medium-grade metamorphics strongly resemble rocks at Frenchmans Cap, the upper Mersey-Forth area and Ulverstone, and are assigned to the *Older Precambrian* (Spry 1962a). Moderately deformed but unmetamorphosed sediments resemble rocks between Zeehan and Corinna and along the North-West Coast (Spry 1957a, 1964) and may be *Younger Precambrian*. Slightly deformed conglomerates, greywackes &c. do not resemble Precambrian rocks elsewhere in Tasmania closely but are probably Younger Precambrian.

ROCKS OF OLDER PRECAMBRIAN TYPE

These rocks are distinguished by their metamorphism and deformation. They are divided into (1) a *Schist-Quartzite-Amphibolite Assemblage* containing regionally metamorphosed sediments and basic igneous rocks belonging to the quartz-albite-epidote-almandine subfacies of the Greenschist Facies and possibly the Almandine Amphibolite Facies (Turner and Verhoogen, 1960). (2) A *Quartzite-Phyllite Assemblage* containing low grade regionally metamorphosed sediments belonging to the quartz-albite-moscovite-chlorite subfacies of the Greenschist Facies.

Petrological examination shows that the metamorphism was accompanied by two periods of deformation and in the following descriptions, the criteria and terminology of Spry (1963a, 1963b) are used; S_0 is bedding, the first deformation F_1 produced a foliation S_1 and a lineation L_1; the second deformation produced S_2 and L_2 &c.

I. Schist-Quartzite-Amphibolite Assemblage.

Dark grey schists outcrop extensively on the wave-cut platform extending northwards from Kelly Basin beyond Bond Bay. The schists to the

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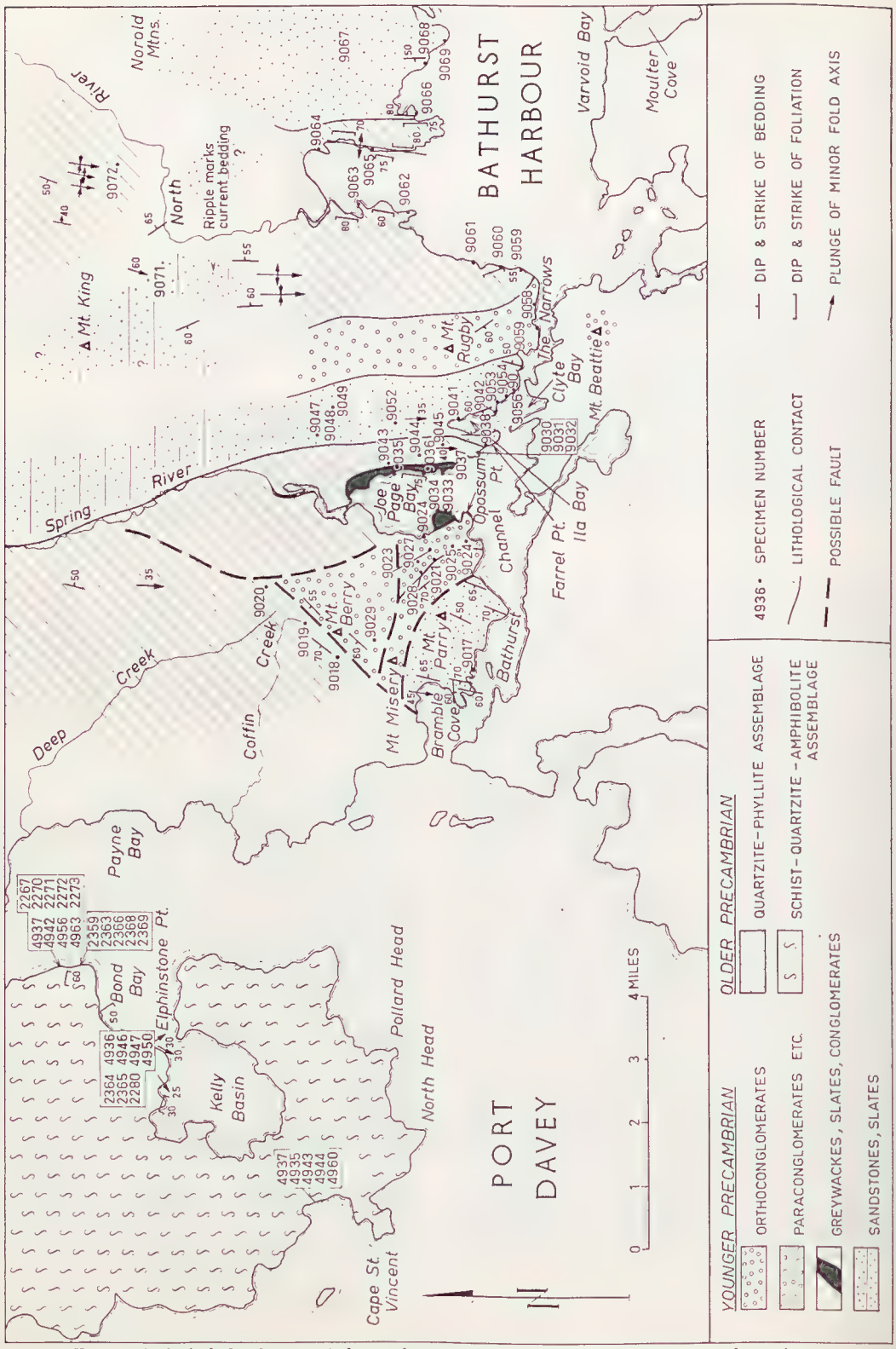


FIG. 1.—Geological sketch map of the northern side of the Port Davey-Bathurst Harbour Area.

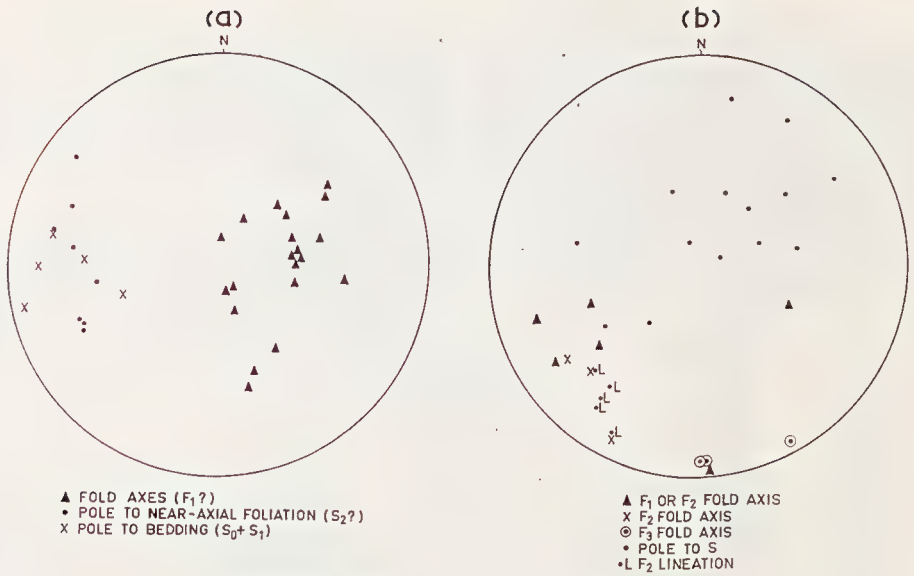


FIG. 2.—Structural data—
(*a*) Folds with discordant non-axial foliation, Davey-Crossing saddle.
(*b*) Fold axes, lineations and foliations in the Bond Bay area.

south are rich in garnet whereas those to the north contain abundant albite. Minor garnet-quartzites outcrop at Kelly Basin and amphibolite bodies occur 1 mile north of Bond Bay. The foliation strikes at between 100° and 160° and dips are moderate to the south and south east.

Small isoclinal folds of a colour banding (S_0?) occur within layers parallel to the main foliation (S_2) and plunge at about 40° towards 220° (Plate I., No. 1, fig. 2). These may be F_1 folds in which the axial surface cleavage (S_1) is paralled to, and masked by, S_2, but are more likely to be F_2 folds.

Lineation (ribs in quartzite, elongate envelopes to garnets) is not widespread but is strongly developed in places and is regarded as L_2. Measurements show that it plunges flatly towards about 220° (fig. 2).

Kink zones, crenulations, and folds up to ten or twenty feet across have a different tectonic style. They are essentially *parallel* folds and disturb S_0, S_1 and S_2; they have no axial-surface foliation and no mineral growth is associated with them (Plate I., 5 and 6). Both macroscopically and microscopically these folds have the characteristics of F_3 folds (Spry, 1963a, 1963b). These structures are strongly developed just east of Bond Bay where they are associated with faulting. A few rather open *similar* folds plunging flatly towards 145° near Kelly Basin probably belong to F_3.

Fine-grained schists (such as 4936*, 4946, 4947, 4950) consist of small (1 mm.) porphyroblasts of garnet in a foliated matrix of muscovite flakes (0.6 mm. long) with lesser biotite; albite occurs as lenticular crystals about 0.4 mm. long and in fine-grained lenticular aggregates. The garnet contains snowball structure (Plate II., No. 3) and is syntectonic but the internal surfaces (S_i) are discordant with S_e (the foliation in the surrounding matrix). Some albite contains simple helicitic structure discordant with S_e. The mica which outlines the foliation wraps around both garnet and albite which are thus older than the foliation (i.e. pretectonic). The S_i within albite and garnet are thus taken to be an old foliation S_1. The garnet is the same age as S_i and is syntectonic to F_1; the albite is younger than S_1 and is post-tectonic to F_1. The main foliation is thus S_2. Some albite is lenticular along S_2 and contains no S_i, this is probably syntectonic and of the same age as S_2. The muscovite and biotite which outline S_2 are interwoven and lenticular; these are taken to be both largely of similar age to S_2, and thus syntectonic to F_2; both micas occur in pressure shadows around garnet. Quartz forms elongate blobs along both S_1 and S_2 and is probably syntectonic to both F_1 and F_2.

The foliation S_2 has been crenulated with the incipient development of a fracture cleavage S_3 along which some biotite may possibly have grown. Chloritization of garnet is a very late process as the chlorite is randomly oriented.

The coarse-grained schists (such as 4935 and 4944) consist of albite porphyroblasts about 1 cm. across separated by irregular layers of contorted mica (about 1 mm. across). The albite is undulose and somewhat shattered, it contains helicitic structure with S_i discordant with S_e and the muscovite wraps around it. Albite is post-tectonic to an early phase but pre-tectonic to the main foliation which is thus S_2. It is so abundant in some

* Numbers refer to specimens in the collection of the Geology Department, University of Tasmania.

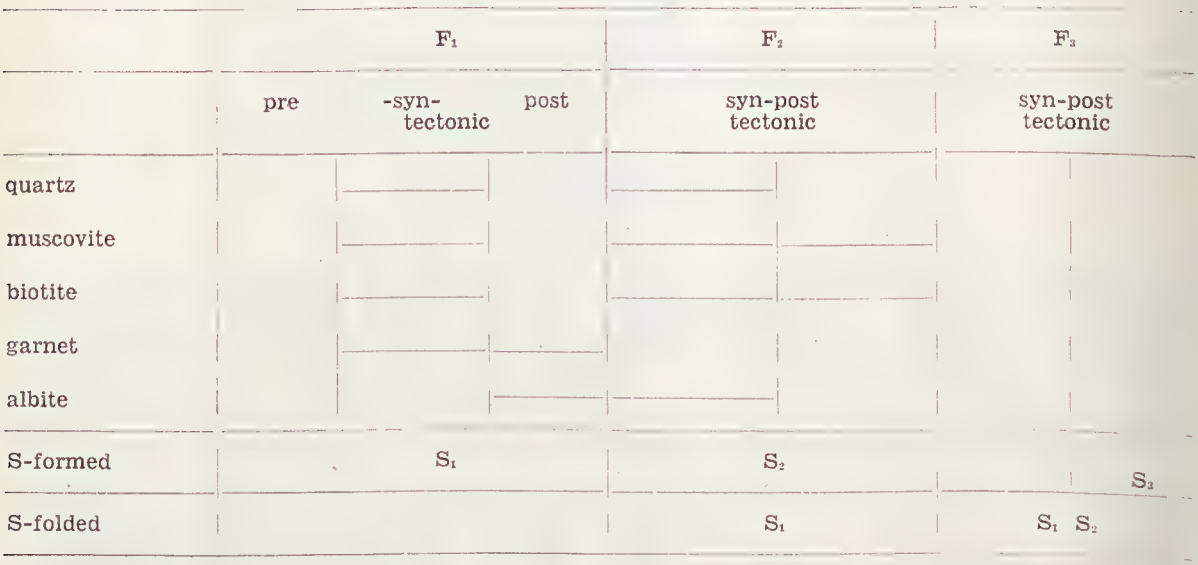
specimens (2363, 2368) that inter-tectonic metasomation is suggested (Gee, 1963; Spry 1963b, p. 117). The analysis in Table II shows 4% Na_2O. The garnets are very small (less than 0.1 mm.), are structureless and mostly contained within the albite although they also occur outside it. Many garnet crystals are fractured and in No. 4944 a lenticular aggregate of very thin grains apparently represents a granulitized large crystal. The garnet is of similar age to the albite but is a little older; it is post-tectonic to F_1 (i.e. later than S_1).

The main foliation S_2 is very irregular and contorted but the muscovite or biotite which outline it are younger than the folding of the foliation (i.e. are post-tectonic). This is indicated by the random disposition of the biotite within the foliation layers in 4944 and by the form of the muscovite in 4935. In this rock the mica flakes are not bent around the hinges of the crenulations as they would if they were present before the folds were formed. Instead individual flakes meet at the hinges indicating crystallization after the folds were formed.

The main differences between the fine- and the coarse-grained schists is that crystallization was largely syntectonic (to F_2) in the fine and post-tectonic in the coarse. The third phase of deformation affected the coarse rocks more strongly.

Chronology of crystallization and deformation of the garnet schists.

TABLE 1.



Regionally metamorphosed basic igneous rocks occur within the garnet-mica schists. The simplest rocks consist of garnet, olive-green actinolite and albite with different amounts of biotite, chlorite and zoisite and accessory sphene, rutile and iron ore. The analysis (Table II) indicates that the rock was probably of olivine basalt type and is similar to amphibolites from the Raglan Range and the Lower Forth River.

An amphibolite mass about 200 yards across is exposed on the wave-cut platform about 1 mile northeast of Bond Bay. It lies among albite-rich schists which strike at 100° on the northern contact and 90° on the south with steep dips to the south. Both contacts are very disturbed and appear to be faulted. The amphibolite is weathered but it can be seen that the core is massive (2370, 2732) and that the material becomes schistose towards the margins (2274, 2273, 4956) with oblique mylonitized bands (2274) and thin light coloured zones which are very rich in feldspar (2369, 2374).

The transitions agree with the observations of Spry (1963b) in the Frenchmans Cap area. The massive centre is of coarse amphibolite containing large strained and bent pale amphibole crystals, broken andesine (Ab_{60}) and garnets belonging to F_1 but distorted by F_2 movements. These grade into schistose amphibolites in which all F_1 minerals except garnet relicts have been replaced by fine grained amphibole which is syntectonic (to F_2) and also ziosite and albite. Some varieties are very rich in albite (e.g. 2369, which has 1 cm. wide layers of fine-grained feldspar) which would appear to have been introduced (Plate I, No. 2). This albite is lenticular and at least part has been crystallized syntectonically (F_2) along the S_2 foliation. Introduction of albite could have taken place intertectonically between F_1 and F_2 and the richness in albite of some schists here suggests they may have been metasomatized also.

Specimens 4937 and 4942 contain large amphibole crystals up to 5 mm. across enclosing garnet. The

large pale green actinolites in 4942 are undulose and fractured and were formed earlier than small amphibole, garnet and zoisite crystals. The small garnets are apparently older than the actinolite which is probably post-tectonic to F_1 and is followed by the quartz and albite. A little late chlorite has replaced garnet, and biotite has replaced actinolite.

No. 4956 consists of garnets up to 0.4 mm. across set in a fine parallel aggregate of olive-green actinolite crystals ranging from 0.02 to 0.2 mm. long. The actinolite wraps around the garnet which has been fragmeted and it also fills fractures in the garnet. The garnet is pre-tectonic with respect to the foliation delineated by the actinolite. Albite forms elongate, granular aggregates along the foliation; it is fresh, heals fractures in garnet and encloses actinolite. Apart from a few old undulose crystals the albite is post-tectonic.

Amphibole-biotite schists (e.g. No. 4963) are midway in composition between the pelitic schists and the amphibolites and are similar to a rock from the Raglan Range described by Gee (1963).

No. 4963 is composed of brown biotite flakes up to 4 mm. long with garnet (0.4 mm.), amphibole (0.6 mm.) and quartz (0.5 mm.). Biotite and actinolite are intergrown and apparently formed simultaneously; they form a foliation which appears to be parallel to the axial surface. In thin section the major foliation marked by muscovite wraps around albite porphyroblasts and cuts through the crests of folds of compositional layering. The albite contains helicitic structure in which S_i (dusty inclusions probably marking S_0) is contorted and is discordant with S_c. The albite is pretectonic to the main foliation but is of post-tectonic type and later than folded S_0. It seems likely, in view of the history of the rocks to the south, that the albite is inter-tectonic between F_1 and F_2 and that the major foliation is S_2. S_2 coincides with S_0 and S_1 except on the crests of folds.

The occurrence of a lime-bearing plagioclase, andesine Ab_{60}, in the amphibolite is important. Previously only albite with a low anorthite content (Ab_{92-98}) has been found in Tasmanian Precambrian metamorphic rocks and this is the reason why almandine and kyanite-bearing schists have been allocated to the Greenschist Facies rather than the Almandine Amphibolite Facies. Most of the schists have such low lime and high soda that a lime-bearing plagioclase might not occur even in high grade rocks but amphibolites in the Frenchmans Cap area contain albite also. Almost all of the albite in the schists belongs to the inter-tectonic period between F_1 and F_2 but it is possible that the Almandine Amphibolite Facies was reached during F_1 and that the Greenschist Facies minerals belong to the inter-tectonic period and to F_2. Tectonic inclusions of Eclogite and possibly Granulite Facies rocks in the Franklin Group on the Collingwood River might also be relicts of an early high grade episode.

Distribution of the Schist-Quartzite-Amphibolite Assemblage.

Descriptions by Stefanski (1957 pp. 101-106) indicate that similar rocks (garnet and albite-mica schists, quartzites and amphibolites) occur at Cox Bight and Red Point. They appear to extend northwards past Ray River and Umbrose Creek to Moulters Inlet and Fulton Bay on Bathurst Harbour. Stefanski also reported similar rocks at Wilson Bight and Ketchem Bay. It has not been possible to confirm the presence of the cordierite, andalusite and chiastolite reported by Everard (in Stefanski, 1957, p. 105) and examination of specimens at the Mines Department suggests that albite has been mistaken for these minerals.

TABLE II.

SiO_2	43.16	44.78	73.1
Al_2O_3	16.12	13.44	13.6
Fe_2O_3	2.89	2.41	0.80
FeO	14.86	16.22	3.3
MgO	5.89	7.01	1.05
CaO	10.22	9.12	0.66
Na_2O	1.63	1.65	4.0
K_2O	0.32	0.47	1.18
H_2O +	2.68	1.58	1.40
H_2O —	0.18	0.07	0.39
TiO_2	2.00	2.81	n.d.
MnO	0.24	0.36	
P_2O_5	0.12	0.04	
	100.31	100.32	99.47

(1) Amphibolite, (4956) Bond Bay, Port Davey, *Anal. Tas. Mines Dept.*

(2) Amphibolite, Raglan Range (Spry 1962a). *Anal. Tas. Mines Dept.*

(3) Albite Schist, 2368, Bond Bay. *Anal. R. L. Bruce and L. W. Castenelli, A.M.D.L.*

II. *Quartzite-Phyllite Assemblage.*

Strongly deformed but low grade meta-sediments outcrop extensively just north of Farrell Point on the south-eastern side of Joe Page Bay (Long Bay of Jennings 1960 &c.) extending in a narrow belt for at least five miles north along the Spring River, and also extensively around the north-western side of Bathurst Harbour and to the north beyond the North River. This assemblage includes Baker's (1957) "Bathurst Shales" "Lindsay Quartzite" and "North Quartzite". It probably also includes Taylor's (1959), "North River Schist" and possible the "Solly River Quartzite" and "Old River Schist".

The rocks around the north-western section of Bathurst Harbour are glossy black phyllites and schists which have pronounced foliation and are tightly folded. Small chevron and conjugate folds belonging to F_3 have folded a foliation and an old lineation and produced a fracture cleavage S_3 along which there is no mineral growth. Small (down to microscopic size) isoclinal folds may belong to F_2 and the major foliation is probably S_2. S_1 is visible under the mricroscope as folded remnants between layers of S_2; S_0 may be represented as helicitic structures within albite. The dark meta-pelites consist of quartz and muscovite with minor chlorite, albite and graphite. Abundant tiny pits may represent weathered out chloritized garnet. The rocks resemble the Dove Schist of the Upper Mersey River. The simplest type (e.g. 9063) consists of finely grained quartz and muscovite

both of which are elongate parallel to a pronounced foliation (S_2). Crenulations produce a fracture cleavage S_3.

More-common are varieties such as 9059, 9061, 9062 and 9065 which are dominated by a strong foliation along which there are layers richer in quartz or in muscovite and lines of opaque material, much of which is graphite. Contorted fold crests and disrupted limbs of old folds lie between the layers of the major foliation and contorted lines of tiny opaque grains or slightly curved bleds of quartz are enclosed helicitically in lenticular albite crystals. The coarse lithological layering visible macroscopically, together with the lines of graphite particles (Plate II, No. 5) probably represent bedding (S_0(which has been disrupted and is now parallel to the main foliation S_2. Remnants of S_1 still remain between the layers of S_2 and helicitically in some albite. The S_i of the helicitic structure (S_0 and S_1) in the albite is discordant with S_2. Lenses and sheaves of chlorite grow athwart S_2 and are post-tectonic to S_2; from the shapes of the aggregates, it would appear that chlorite has replaced biotite and garnet belonging to F_1.

These rocks are phyllonites and probably were formed by retrograde metamorphism from garnet or muscovite-biotite schists. The higher grade minerals garnet and biotite from F_1 were replaced by chlorite during F_2. Albite was inter-tectonic between F_1 and F_2. these rocks from Bathurst Harbour may really belong to the schist-quartzite assemblage but garnet has not yet been found.

Quartzite (e.g. 9072, the "North Quartzite" of Baker, 1957) occurs along the North River, 3 miles north of North Inlet. Massive and crenulated schistose quartzites are folded and show several lineations. No. 9072 (Plate I, No. 4) is a white, somewhat platy quartzite. An F_1 fold of bedding (S_0) and a bedding plane foliation (S_1) are crossed obliquely by a foliation (S_2) which is visible microscopically and the S_2-S_1 and S_2-S_0 intersections give a lineation L_2 which is oblique to the fold axis. Petrofabric analysis shows a strong preferred orientation of quartz with a girdle normal to L_2. In thin section the rock is a fine-grained quartzite with about 5% of muscovite as tiny flakes aligned crudely along S_2. The quartz is undulose and irregularly shaped with a slight tendency towards elongation along S_1.

The rocks ("Lindsay Quartzite" of Baker 1957) in the narrow belt extending north from Farrell Point (east of Joe Page Bay) along the Spring River, are somewhat similar. The quartzites (e.g. 9044) are tightly folded lustrous, foliated and lineated. No. 9044 is a fine-grained quartzite containing folds of about 8" wage length, with a foliation along the bedding and another parellel to the axial surface of the folds. The intersection of these foliations gives a lineation parallel to the fold axes. The folds are neither *similar nor parallel* as the thickness of the layers varies when measured either orthogonally to the bedding or parallel to the axial surface.

In thin-section the rock is finely crystalline and is composed of interlocking quartz grains with blurred margins, strongly elongate parallel to the axial surface and the axis of the fold. Sparse micas occur in bands (S_0) and outline a foliation (S_1) parallel to the bedding. A petrofabric diagram shows a strong preferred orientation of quartz in a broken girdle normal to the lineation. The pattern is similar to that of the quartzite (9072) from the North River.

Micaceous quartzites (e.g. 9043, 9045) occur in this belt also.

Massive white quartzites (9020), foliated and lineated quartzites (9019), and light grey, glossy crenulated phyllites (9018) extend from the north-western slopes of Mt. Berry to Coffin Creek ("Berry", "Western" and "Coffin" Quartzites of Baker, 1957). These show many of the characters of the older Precambrian rocks but are not as strongly deformed as the rocks described above. in thin section, the phyllite No. 9018 is strongly foliated and consists of alternate layers rich in muscovite or elongate quartz. Remnants of an old foliation are visible as discordant trails of muscovite across the quartz lenses. Some quartzites (e.g. 9019) are white, foliated and lineated. In thin section the quartz, which is undulose with deformation lamellae, forms slightly elongate but irregularly shaped crystals with blurred margins. Twisted muscovite flakes outline the foliation.

Rocks of Younger Precambrian Type.

Quartzites, conglomerates, slates and phyllites, which have been folded tightly in places but which are not regionally metamorphosed, are abundant in the Bathurst Harbour region. These rocks are much less deformed than those included in the older Precambrian assemblages in that bedding is clearly visible. A single cleavage is present in most rocks and a second (fracture) cleavage develops in places. These sediments resemble younger Precambrian rocks of the Zeehan-Smithton-Burnie area (Spry, 1964) but have a different and simpler tectonic syle than the older Precambrian metamorphics. The conglomerates contain abundant pebbles of foliated and lineated quartzite, phyllite and schist which are identical with the older Precambrian rocks of the district so that a major tectonic and metamorphic episode (presumably the Frenchman Orogeny) separated the two groups. An actual surface of angular unconformity has not been observed.

Three main lithological assemblages are recognized: I. *Quartzites and slates.* These include the sediments to the north-east of Bathurst Harbour ("Old River Quartzite and Meta-Pelite" of Baker, 1957; "Upper Member of the Moulter Cove Formation" of Taylor 1959); the narrow strip extending north from Ila Bay along the eastern side of the Spring River ("Ila Bay Quartzite and Conglomerate" of Baker, 1957), and the sediments between Bramble Cove and Mt. Parry ("Bramble Quartzite and Meta-Pelite" of Baker, 1957). II. *Orthoconglomerates and quartzites.* Thick white quartz-conglomerates occur at Mt. Rugby, Mt. Mackenzie, Mt. Berry, Mt. Misery, Mt. Beattie ("Mackenzie Conglomerate", "Rugby Conglomerate" and "O'Possum Conglomerate" of Baker, 1957). The relations of these conglomerates to each other and to other rocks in the area are not clear but it is tentatively assumed that they are equivalent to

each other and belong to the younger Precambrian assemblage. III. *Greywackes and paraconglomerates.* Dark-coloured, poorly sorted sediments with abundant sedimentary structures occurring at Joe Page Bay ("Long Bay Shale" of Baker, 1957) may be younger Precambrian.

I. *Quartzites and Slates.*

Quartzites and slates outcrop along the northern shoreline of Bathurst Channel between Bramble Cove and Mt. Berry. They strike at about 25°, dip steeply (60°-70°) to east and west, and have been folded about axes plunging at up to 45° towards about 190°. On the eastern shore of Bramble Cove, slates become contorted in the core of a small anticline and there are segregations of quartz (Nos. 9010, 9012, 9013).

The quartzites range from deformed and recrystallized varieties such as 9017 which consists microscopically of a mosaic of inter-locking undulose quartz and 9016 with mortar texture to impure varieties such as 9015 with about 10% of feldspar (microcline) and 10% of sericite outlining a foliation.

Most of the pelites are recrystallized quartzose siltstones. In 9014, quartz comprises about 40% of the rock as irregular and lenticular crystals about 0.1 mm. long in a foliated matrix of fine sericite. A few flakes of clastic muscovite about 0.3 mm. across are present, together with accessory tourmaline, tiny rutile needles and rounded grains of zircon. Mica-rich varieties such as 9022 are light coloured, glossy phyllite with a strong foliation and several irregular lineations produced by fine crenulations. Macroscopically these rocks resemble the glossy slates of the Oonah Quartzite and Slate near Zeehan but some thin sections show the tiny quartz grains to be strongly elongate parallel to the fine muscovite giving a texture somewhat similar to some of the simpler varieties of Whyte Schist. Specimen No. 9010 from the core of the anticline at Bramble Cove is tightly contorted and in thin section looks like a fine-grained contorted mica schist. No. 9013 contains a little fresh, light brown biotite.

The rocks outcropping along the north-eastern shoreline of Bathurst Harbour and across the plain to the north ("Old River Quartzite and Metapelite" of Baker, 1957) resemble those at Bramble Cove. Quartzite is the dominant rock-type; the purer varieties are white but some weathered examples are brown and ferruginous. They are thinly bedded with a bedding-plane cleavage. Quartzites (9068 and 9069) are similar to the feldspathic quartzite (9015) from Bramble Cove but contain a little more feldspar (about 20% of albite and microcline).

The phyllites are light-coloured with a cleavage oblique to the bedding. In thin-section, specimens such as 9070 are composed mainly of closely packed sericite flakes forming a strong foliation with about 10% of quartz as lenticular crystals or aggregate along the foliation. Jennings (1960, p. 183) observed ripple marks, cross-bedding and mud-cracks in quartzites at the mouth of the Old River. These features extend for at least a mile south along the eastern shore of the harbour. Ripple marks and cross-bedding were also observed east of the North River and on the northwest slopes of Mt. Berry.

The sediments forming a narrow belt from Ila Bay north along the eastern side of the Spring River ("Ila Bay Quartzite and Conglomerate" of Baker 1957, "Younger Precambrian" of Jennings 1960, p. 183) differ somewhat from the rocks at Bramble Cove and the Old River. Quartzites, which are the dominant rock type, are white to grey and commonly flecked with tiny fragments of black shale or have abundant clastic muscovite flakes along the bedding. They have a distinct cleavage oblique to the bedding and some contain isoclinal folds (No. 9053).

The coarser varieties (9048, 9052) are poorly sorted with large quartz grains (0.3 mm.) set in a fine-grained (0.5 mm.) quartz-sericite matrix. Bedding is outlined by parallel clastic muscovite flakes and the oblique cleavage by tiny sericites. These rocks grade into coarse siliceous siltstones (9053, quartz 0.05 to 0.02 mm.) with up to 40% sericite.

The pelites (9041, 9054) are siliceous siltstones containing about 55% quartz (.01-.02 mm.), 40% fine parallel sericite giving a foliation and about 5% clastic muscovite. Accessories are tourmaline, rutile and zircon.

The rock underlying the saddle between the Spring and Crossings Rivers is a slaty siltstone (No. 2357). It is buff coloured with a strong cleavage. Original bedding strikes at about 340° and dips east at 40°, and the strongest foliation (S_2) strikes at about 160° and dips east at about 50°.

A thin section shows that the rock is finely grained and consists of quartz and fine muscovite. Bedding which consists of compositional layering has been deformed and dismembered. Parallel to bedding is a foliation shown by parallel mica flakes. This foliation (S_1) has been crenulated and a strong, closely spaced, fracture cleavage S_2, has developed along the appressed limbs of the asymmetrical contortions.

White quartz-conglomerates and pebbly quartzites are interbedded with the quartzites at Ila Bay, particularly on the eastern side of the belt. These contain subangular to subrounded fragments of metamorphic quartzite (with a strong foliation &c.), fine-grained mica-scist, phyllite, undulose quartz, muscovite flakes, tourmaline grains and also fragments of fine-grained quartzite and phyllite similar to the adjacent rocks with which the conglomerates are apparently interbedded. The sediments have not been recrystallized and show little evidence of deformation. The matrix of the granules and pebbles is coarse to fine sand-size rock- and mineral-fragments.

In general, the rocks at Ila Bay are similar to sediments thought to be of younger Precambrian age in north-western Tasmania e.g., the Oonah and Burnie Quartzite and Slate. The presence of conglomerates is important as it suggests a close relationship between the Ila Bay sediments and the thick conglomerates at Mt. Rugby &c. Jennings (1960, p. 183) observed pebbles in these sediments

at the Spring River and suggested that the presence of worm casts indicated a possible correlation with the Rocky Cape Group.

II. *Orthoconglomerate—quartzite Assemblage.*

Massive white quartzose conglomerates containing fragments of the older Precambrian metamorphic rocks cap many of the higher mountains in the area. Conglomerate extends from the peak of Mt. Rugby south to the shoreline at the Narrows and apparently further to Mt. Beattie. The formation strikes at 170° and dips west at 75° and is presumed to overlie the schists of Bathurst Harbour unconformably. The actual contact is not exposed and the attitudes of the rocks above and below the contact are similar.

The conglomerates contain pebbles and boulders up to six inches in diameter. Breccias and pebbly sandstones are common. The sedimens are sheared and smashed in places but contain a single indistinct foliation. The elongate, ellipsoidal form of some pebbles is probably an original feature and not due to deformation of the conglomerate.

Thin sections (9057, 9058) show that the rocks are moderately well-sorted, contain angular to subrounded fragments and have no cement and very little matrix. The rock-fragments include metaquartzite, mica-schist, phyllite and slate, most of which are identical with the metamorphic rocks of the older Precambrian in the vicinity, with some pelitic fragments rather similar to members of the younger Precambrian *quartzite-slate assemblage.* In general there is no matrix or cement and the particles are held together by phyllite and slate fragments moulded around and between the quartzite particles, but a thin sericite layer cements some fragments.

Similar conglomerate extends from Mts. Berry, Misery and Mackenzie south to Bathurst Channel. Pebbles range up to eight inches in diameter and are mostly pelitic rocks in the lower part of the formation and quartzites in the upper part.

The age of these unfossiliferous conglomerates is not known. Stefanski (1957, p. 94) remarked on their similarity to the Ordovician Owen Conglomerate and Jennings (1960, p. 180) suggested that they might be Cambrian. The conglomerates are not unlike the Owen but are much more siliceous and are better sorted than the conglomerates of the Cambrian Dundas Group. They are not unlike Precambrian conglomerates in the Donaldson Group (Spry 1964) and as conglomerates occur within the quartzites and slates at Ila Bay, it is suggested that the conglomerate at Mts. Rugby, Berry, Mackenzie, Misery and Beattie is younger Precambrian in age.

Conglomerates, sandstones and slates which outcrop on the eastern slopes of Mt. Mackenzie down to Opossum Point ("Opossum Conglomerate" of Baker 1957) are intermediate in character between the orthoconglomerates described above, and the paraconglomerates and associated sedimens described above, and the paraconglomerates and associated sediments described later from Joe Page Bay.

Quartzose conglomerates (9024, 9028) in the upper part of the formation are similar to those of Mt. Rugby &c. except that the metamorphic rock fragments are held together by a recognizable sand-silt matrix (sericite and quartz) which constitutes about 30% of the rock. Grey paraconglomerates (9023, 9025) are rich in dark-coloured (carbonaceous) slate fragments and have an abundant matrix. The matrix is cleaner in 9023 and many of the larger fragments are rounded to well-rounded. Grey quartzites (9029) are somewhat similar to those at Ila Bay and the north-eastern part of Bathurst Harbour. They consist dominantly of sand-grade, angular quartz fragments with a few particles of mica-schist, slate and meta-quartzite in a weakly foliated sericitic matrix (10%). Interbedded grey sandstones and siltstones (9027) contain a single cleavage oblique to well developed bedding.

III. *Paraconglomerate—greywacke Assemblage.*

Dark coloured conglomerates, greywackes, slates and shales occur around the coastline of Joe Page Bay ("Long Bay Shale") of Baker 1957 and Jennings 1960).

The sediments at Joe Page Bay are dark greywacke sandstones and shales or slates displaying graded bedding, slump structures, flame casts &c., with a few lenses of dark conglomerate. The rocks dip steeply, some being overturned, have a cleavage oblique to the bedding and have been folded. The authors cannot agree with the statement of Jennings (1960, p. 181) that "the rocks have suffered little more deformation than our Permian sequences". The name Long Bay *Shale* was a misnomer as the pelites are not shales but slates and in any case, pelites are not overwhelmingly dominant.

The most common rocks are well cleaved, poorly sorted siltstones and fine-grained sandstones containing abundant labile rock fragments and minerals. Carbonaceous material gives many of the rocks a dark colour.

In thin section, greywacke sandstones such as 9035, 9036 and 9037 consist of closely packed, elongate and angular fragments of mica schist, phyllite, slate, metamorphic quartzite and quartz. The matrix is difficult to recognize but irregular wisps and sheaves of parallel authigenic sericite and chlorite occur between the fragments. Fresh albite constitutes not more than 5% of the rocks.

Finely grained dark conglomerates such as 9022 consist of well rounded rock fragments in a dark, carbonaceous and weakly fissile silt matrix. Conglomerates such as 9033 are light coloured and consist of sub-rounded quartzite fragments in an abundant, cleaved, quartz-sericite matrix.

STRATIGRAPHY

The main conclusion which can be drawn from this petrographic study is that the rocks can be divided into two main types, each of which has equivalents elsewhere in Tasmania.

The metamorphic rocks of Bond Bay, North Inlet, and Cox Bight have a complex structural history and are identical with rocks considered to be older Precambrian elsewhere in Tasmania.

The remainder of the rocks are assigned tentatively to the younger Precambrian. The sediments at Bramble Cove, at Ila Bay and in the north east of Bathurst Harbour are similar to the Oonah (or Burnie) Quartzite and Slate. The greywacke assemblage at Joe Page Bay might be equivalent to the Cowrie Siltstone and the Interview Slate. The thick conglomerates and quartzites at Mt. Berry &c., could be equivalent to the Donaldson Group.

The sediments at Joe Page Bay differ markedly in lithology from those elsewhere in the area with the possible exception of some rocks from Clyte and Varvoid Bay, described by Stefanski (1957, pp. 91, 92). Their degree of deformation is compatible with that of rocks considered to be of probable younger Precambrian age. The sedimentary structures indicate affinities with the greywackes even though they are deficient in matrix and labile minerals. They appear to grade upwards into the subreywacke assemblages at Opossum Point and thence into the orthoquartzite conglomerates of Mt. Rugby.

Stefanski (1957, p. 92) suggested a glacial origin for the rocks at Clyte Bay but no striated pebbles have been found and the sediments are regarded as "turbidites".

The sediments do not closely resemble the Dundas Group. Sedimentary structures are developed more strongly than in the Dundas Group, and cherts are not present. Perhaps most important is the lack of volcanics either as lavas or as particles in the conglomerates and sandstones. Fragments of fine-grained volcanic rocks and chert are typical of Dundas Group sediments everywhere but appear to be absent in the Joe Page Bay sediments.

The following stratigraphic succession is tentatively suggested along with possible correlations which should be taken to indicate lithological similarities rather than necessarily time equivalents.

TABLE III.

Age	Rock Type	Locality	Similar Rocks
Younger Precambrian	Orthoconglomerate	Mt. Rugby, Beattie, Berry, Misery, Mackenzie, Opossum Pt.	Donaldson Group
	Greywackes, slates and paraconglomerates	Joe Page Bay	Cowrie Siltstone
	Subgreywacke sandstones and slates	Ila Bay, Bramble Cove, north-eastern Bathurst Harbour	Oonah Quartzite and Slate
Older Precambrian	Quartzite and phyllite	North River, Farrel Pt., Coffin Creek, (North-western Bathurst Harbour?)	Mary Group
	Schist, quartzite and amphibolite	Kelly Basin, Bond Bay, Red Pt.	Franklin Group

STRUCTURE

The area is dominated by roughly north-south strikes and westerly dips. It seems likely that the same rocks (e.g. conglomerates at Mt. Rugby and Mt. Berry) appear in several places dipping in the same direction but in view of the doubtful stratigraphy it is not possible to outline the major structure. Structural highs outlined by the older rocks trend in a northerly direction through Kelly Basin and from Bathurst Harbour to Cox Bight. The work of Taylor (1959, pp. 39-42) suggests another belt of older Precambrian rocks through the Spero Range. The older rocks are separated by strike-faulted synclinal belts of younger Precambrian sediments.

An unconformity between metamorphosed and unmetamorphosed sediments is indicated by the presence of pebbles of metamorphic rocks in unmetamorphosed conglomerates and by a marked discordance in grade of metamorphism and degree of deformation between the two major groups. It is not known whether there is more than one unconformity in the district. Some previous workers (Stefanski 1957 and Taylor 1959) have postulated conformity or lack of conformity between various units without advancing any evidence in support. It has been shown (Spry 1957b; 1962a) that unconformities within the Precambrian are very difficult to recognize and the numerous postulated unconformities in the south-west of Tasmania must be viewed with suspicion until their validity is supported by careful and detailed work.

The correlations made by Taylor and Stefanski must also be viewed with suspicion. It is reasonable to point out similarities in lithology which a worker notes between the rocks in this area and those he has examined elsewhere but correlations such as those of Stefanski (1957, pp. 98-100) and Taylor (1959, p. 41) are more likely to mislead future workers than help them.

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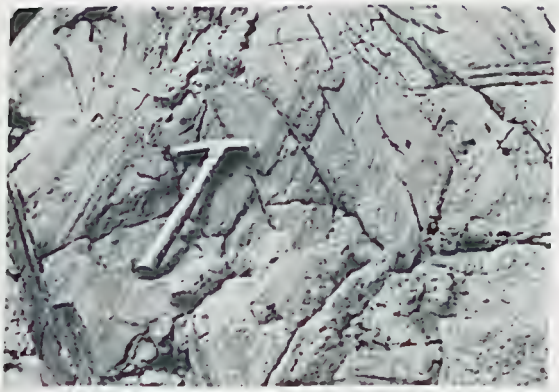

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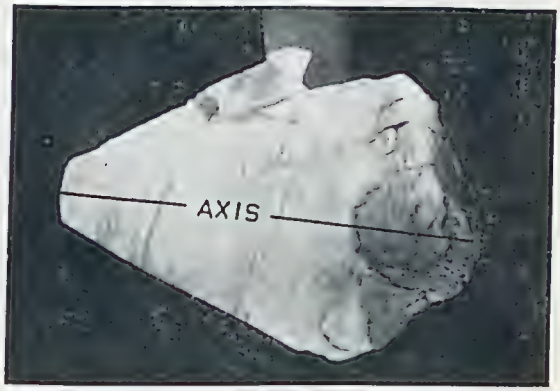

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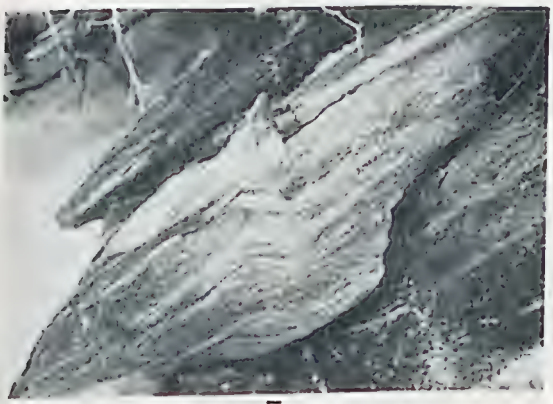

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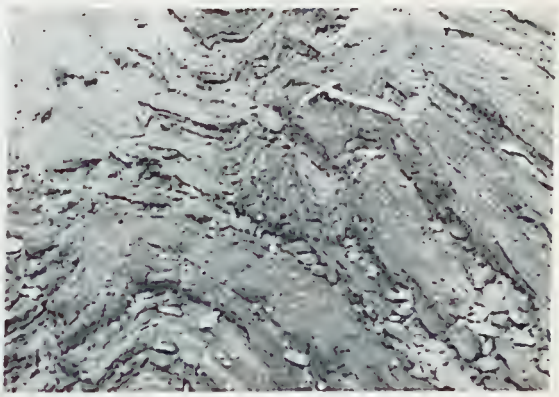

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Plate I.—

No. 1.—Isoclinal (F_2?) folds in mica schist, Kelly Basin.

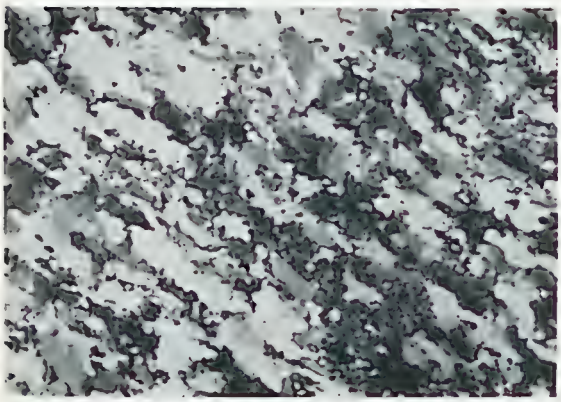
No. 2.—Amphibolite with patches of albite, Bond Bay.

No. 3.—Lineation (L_2) in garnet-mica schist, Bond Bay.

No. 4.—Fold in quartzite with lineation oblique to fold axis. Spec'men No. 9072 from the North River is 3 inches long.

No. 5.—Kink-bands (F_3) in mica schist, Bond Bay.

No. 6.—Folds (F_3), in mica schist, Bond Bay.



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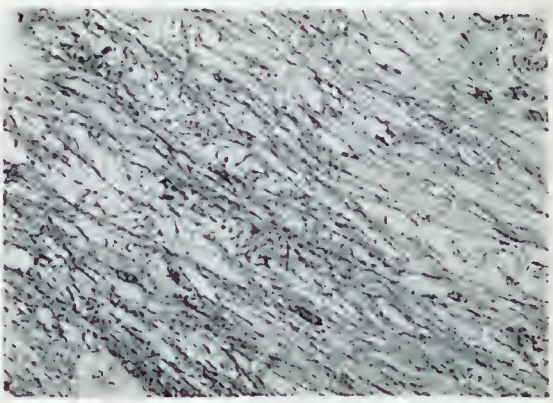

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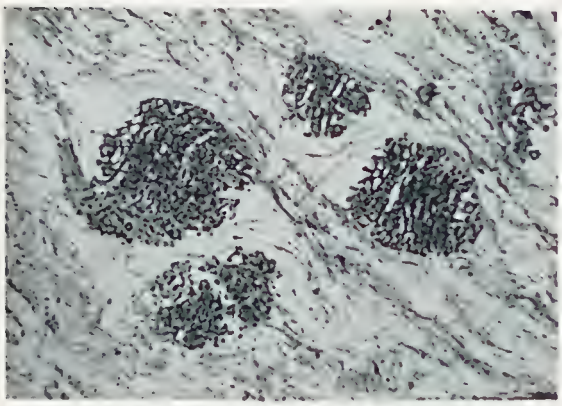

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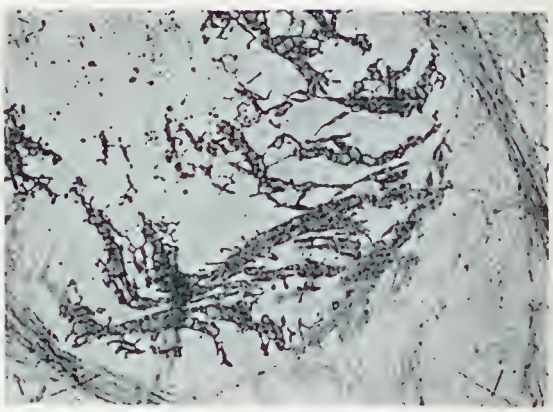

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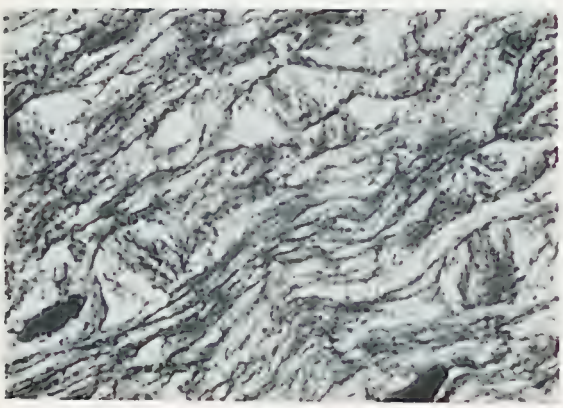

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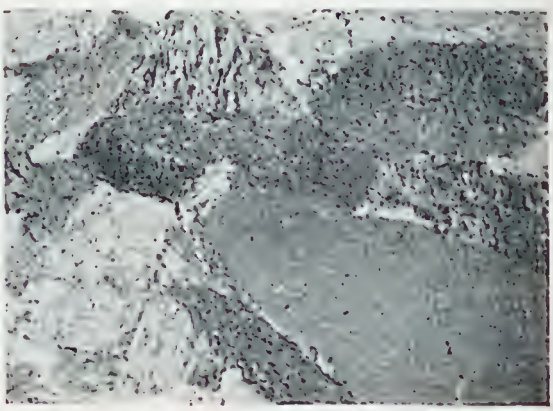

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Plate II.—

No. 1.—Quartzite, No. 9044. Older Precambrian, Farrel Point.

No. 2.—Phyllite No. 9018. Older Precambrian, Bathurst Harbour. The main foliation is S_2 with relicts of folded S_1, between the layers.

No. 3.—Snowball garnets in mica schist, No. 4946, Coast West of Kelly Basin.

No. 4.—Skeletal garnet in schist No. 4965. Coast west of Kelly Basin.

No. 5.—Albite crystals enclosed by S_2 and including S_0 as Si. Specimen No. 9062, phyllite, Bathurst Harbour.

No. 6.—Paraconglomerate, Joe Page Bay.

THE GEOLOGY OF THE MT. ELEPHANT-PICCANINNY POINT AREA, TASMANIA

By

R. D. McNeil.

(With nine text figures.)

ABSTRACT

The oldest rocks are very slightly metamorphosed Siluro-Devonian sediments (Mathinna Beds)—greywacke sandstones, siltstones and mudstones which are mainly of turbidity current origin. The Permian System (450 ft. thick) unconformably overlies the Siluro-Devonian System and consists of lacustrine sandstones, marine limestones, greywacke sandstones, siltstones and mudstones of Artinskian and Kungurian age. Overlying the Permian System, probably disconformably, are up to 850 feet of Triassic freshwater sub-greywacke sandstones with interbedded coal and mudstone that have been intruded by extensive sills and sheets of Jurassic dolerite. A small amount of basalt was extruded in the Tertiary.

The Middle Palaeozoic rocks were closely folded during the Devonian Tabberabberan Orogeny along axes trending north north-west. Towards the end of the orogeny, a hypersthene and sanidine bearing porphyry, and an adamellite stock were intruded into the Mathinna Beds. The porphyry is at least 800 feet thick, may be as much as 5000 feet thick and has been metamorphosed by the adamellite along its southern boundary.

INTRODUCTION

The area mapped consists of two ten thousand yard squares, 6087 and 6086, the Mt. Elephant and Piccaninny Point squares respectively, which are part of the St. Marys quadrangle (Fig. 9). The area is situated on the east coast of Tasmania, east of the township of St. Marys, which is approximately 80 miles by road from Launceston.

Part of the area has been mapped in a regional fashion by Keid (Hills et al. 1922), but his map, and in particular his interpretation of the structure is not accurate. Voisey (1938) carried out some detailed work on the Permian System at Elephant Pass, and Everard (in Hughes 1957) mapped the Berriedale Limestone around the southern part of Mt. Elephant. The Berriedale Limestone in the vicinity of Piccaninny Creek is also described in Hughes (1957).

The writer wishes to thank the staff of the Geology Department of the University of Tasmania for their help and guidance throughout this work.

PHYSIOGRAPHY

The area around and east of St. Marys, with the exception of a narrow coastal plain, and the upper part of the Break O' Day Valley is of strong relief. Mt. Elephant is the highest point, rising from sea level to 2350 feet above sea level in three miles. St. Patrick's Head is 2227 feet high, and the hills west of the coastal plain between Lagoons and Seymour rise to over 2000 feet above sea level. The main hills are capped with dolerite.

Three separate drainage systems are represented. North and west of Gray and Mt. Elephant, all the streams drain west, combining to form the Break O' Day River which is part of the South Esk system. The Break O' Day is essentially a mature river flowing across a flood plain in a relatively broad level valley. In contrast, east of Mt. Elephant the drainage is to the east, and many small creeks descend rapidly through deep gorges with precipitous slopes to the sea. Whereas these creeks descend from over 1500 feet above sea level to sea level in 3 to 4 miles, the Break O' Day which at St. Marys is 900 feet above sea level travels over 120 miles before it reaches the sea. The watershed between these two drainage systems is gradually being worn down, and river capture by the east flowing streams in inevitable in the near future.

The south-western part of the area is capped with dolerite and forms a low plateau averaging 1500 feet above sea level. This area corresponds to the St. Clair level of Davies (1959).

The coastal plain has a width of more than a mile at the southern end of the Piccaninny Point square, decreases in width to the north, and is not present in the Mt. Elephant square. It widens just south of Seymour to more than two miles wide, and is generally underlain by sand and gravels which are of Recent or Pleistocene origin. A wide beach with bordering coastal dunes extends practically all the way down the Piccaninny Point square, but is broken by Piccaninny Point itself, which extends about a quarter of a mile into the sea. The creeks are barred for most of the year, and small lagoons are present near the mouths.

Several coastal levels, which probably represent old sea levels have been recognised. The best developed is approximately 20 feet above sea level and is represented by most of the coastal plain. Others are developed at 60 and 250 feet above sea level. The 60 foot level is well developed in the Mt. Elphant square where a platform up to a quarter of a mile wide has been cut in the St. Marys Porphyry just south of Four Mile Creek.

STRATIGRAPHY

SILURO-DEVONIAN SYSTEM

Mathinna Beds

The Mathinna Beds, the oldest rocks in the area, comprise the steeply dipping sediments unconformably underlying the Permian System. These beds may be a formation, but at present not enough is known to define them as such. A well exposed section occurs on the Tasman Highway between 058,676 and 045,683, but is incomplete and complicated by minor folding and faulting.

The Mathinna Beds are probably partly or wholly equivalent to the Scamander Slate and Quartzite (Walker 1957), and the Mathinna Group (Hills and Carey 1949), with which they are lithologically very similar. They have undergone low grade metamorphism, which was not strong enough to destroy the original textures.

The sediment consists of sandstones, medium to coarse grained siltstones and mudstones. The mudstone layers vary from a fraction of an inch to approximately six feet thick. The sandstones and coarse grained siltstones are poorly sorted, and individual beds vary in thickness from one inch to over three feet. In the sandstone layers all grade sizes from clay to medium sand occur and in the siltstone, clay is always present (seldom less than 30%). The grains are angular to subangular, and consist mainly of quartz, with subordinate fragments of quartzite, chert, mudstone, biotite, muscovite and plagioclase. Graded bedding is common in the coarser sediments where grading is from medium sand grade (Wentworth scale) at the base to silt grade at the top.

Sedimentary structures, particularly cross bedding are well developed in places. The cross beds are of the festoon type, and are extremely small, with laminations rarely thicker than 0.5 mm. The cross beds are often twisted and distorted, probably by turbidity current drag. It is extremely difficult to obtain reliable current directions from these cross beds in the field, and the directions obtained for the source of the currents varied from south to west.

Sole markings similar to those at Upper Scamander (Williams 1959) are well developed. In the Elephant Pass section, just above the saddle at 050,681, flute casts indicate currents from 210 degrees and at 045,675 flute casts indicate currents from 280 degrees.

The sandstones and coarse siltstones were deposited by turbidity currents (Kuenen and Migliorini 1950). The graded beds, disrupted nature of the sandstone, poor sorting and sole markings all support this conclusion.

The mudstones were deposited in quiet conditions from dilute fluid suspension. However, a considerable part of the fine sediment in the mudstones was probably transported by turbidity currents, but because of the fine size of the particles, settling continued long after the coarser sediment had been deposited.

Fragmentary plant remains were the only fossils found in the Mathinna Beds. They are poorly preserved, and unidentifiable, but occur in at least three places, notably 008,768; 005,750 and in the Elephant Pass section a few hundred feet below the unconformity. Cookson (1936) identified plant fragments from lithologically similar beds near Warrentina as possibly *Hostimella*, and considered the rocks to be of Upper Silurian or Lower Devonian age.

PERMIAN SYSTEM

The Permian System consists of 375 to 475 feet of sandstones, greywacke sandstones, siltstones, mudstones, conglomerates, and limestones, which have been divided into six stratigraphic units.

The Permian rocks dip gently in a southerly or south-westerly direction. The difference in elevation between the base of the Berriedale Limestone at the northern end of Mt. Elephant and Piccaninny Creek, after allowing for faulting, indicates a dip of one degree to the south.

A panel (fence) diagram of all the measured Permian sections and bore cores in and around this area is presented as Fig. 1. The sections used in the diagram were obtained from the following sources:—Rossarden—Blisset (1959); Avoca—Banks (1958); Killymoon Bore—Hills *et al* (1922); Harefield Bore—Hills *et al* (1922); Seymour Bore—Hills *et al* (1922); Ray's Hill—Walker (1957). All other sections have been measured by the writer.

Wardlaw Conglomerate

The Wardlaw Conglomerate consists of poorly sorted, unfossiliferous conglomerate and interbedded coarse sandstone. It unconformably overlies the Mathinna Beds and is conformably overlain by the Mt. Elephant Sandstone.

The Wardlaw Conglomerate outcrops boldly, usually as small cliffs, 5 to 10 feet high. Several good sections are exposed in creeks (054,652; 033,682; 041,702), but the most accessible section is on the Tasman Highway in the Elephant Pass (046,683), where it is possible to divide the formation into four members.

The basal member, (about 2 feet 6 inches thick), is a conglomerate, and consists of rounded pebbles (mainly Mathinna sediment) up to 8 inches long, set in a matrix of rock fragments, quartz and minor feldspar. The matrix is poorly sorted and the angular particles range in size from silt to granules 4 mm. in diameter.

Conformably overlying the basal member is a poorly sorted, yellow-brown coarse sandstone, which contains a few scattered, well rounded pebbles and closely resembles the matrix of the basal member. This second unit is 3 feet 6 inches thick, and has a fairly sharp boundary with the underlying unit.

The second member grades into a pebbly sandstone above with a decrease in the grainsize of the matrix and an increase in the number of pebbles. This pebbly sandstone is 4 feet 6 inches thick, with pebbles comprising about 15 to 20% of the rock. The pebbles are rounded, consist mainly of

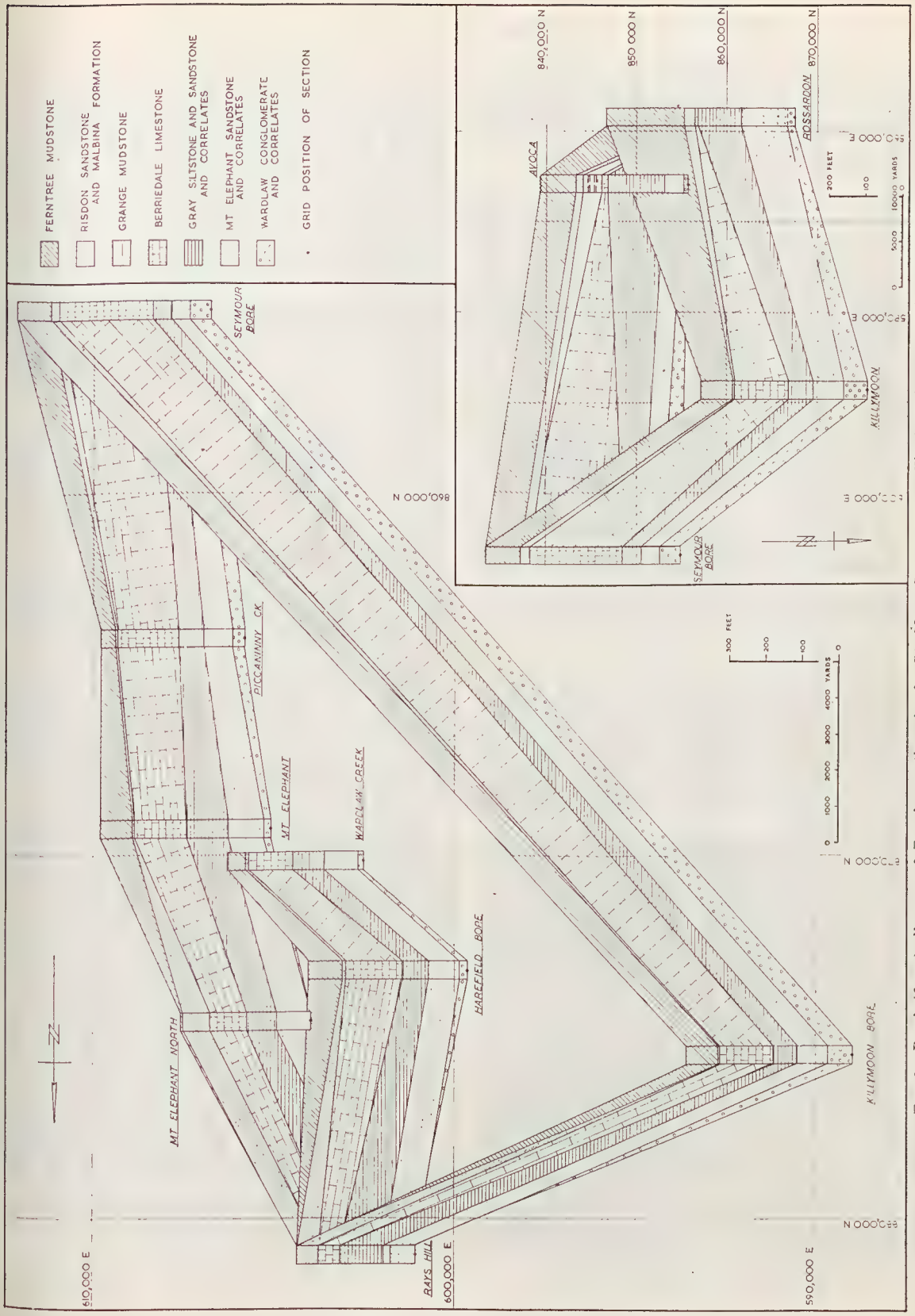


FIG. 1.—Panel (fence) diagram of Permian sections in the St. Marys-Seymour area. The inset is a panel diagram relating Periam sections in the St. Marys area to Permian sections in the Avoca and Rossarden districts.

quartz and Mathinna sediment with rare granite fragments, and vary from about half an inch to one foot in diameter. The matrix is angular and consists of quartz (75%), rock fragments and feldspar (15%). The upper boundary of this unit is distinguished by an increase in the number of pebbles per unit volume.

The fourth member, which is 12 feet thick, is a medium to coarse, poorly sorted conglomerate, which grades into pebble sandstone near the top. The size of the pebbles is much larger than in any of the previous units, and varies from ½ an inch to 18 inches or more. They are rounded with poor sphericity, and are mainly of Mathinna sediments. The matrix is light coloured with orange and yellow streaks, and consists of quartz (75%) rock fragments (20%) and feldspar (5%). It varies in size from silt grade to coarse sand. Conformably overlying this unit are the basal sandstones of the Mt. Elephant Sandstone.

Several other sections of this formation have been measured and they indicate that the proportion of sandstone to conglomerate varies enormously, but in general, conglomerate predominates over sandstone.

In a cliff section at 037,697 cross bedding (3 feet across) and graded bedding occur in a sandstone bed. The graded beds are localised, about 6 inches thick, and grade from very coarse sand at the base to fine sand at the top. Crude graded bedding is also represented in the conglomerate at 056,744.

Mt. Elephant Sandstone

The Mt. Elephant Sandstone is 100 feet thick at the Elephant Pass and consists of quartz sandstone, with interbedded mudstone and shale. Voisey (1938) refers to this formation as part of the St. Marys Basal Stage. Two sections were measured and are summarised in Fig. 2. A is exposed in road cuttings on the Tasman Highway at 046,583, and B in the upper reaches of Wardlaw Creek at 028,706.

Marine fossils are generally absent, but in scattered blocks of sandstone belonging to the Mt. Elephant Sandstone south of St. Marys (005,735), several fenestellids were identified. Fragmentary plant fossils are abundant in a few localities, in association with carbonaceous shales. Spores from these carbonaceous shales have been identified, and indicate that the Mt. Elephant Sandstone is partly or wholly equivalent to the Mersey Group of north-western Tasmania (Banks 1962).

The basal part of the formation is a coarse sandstone 10 to 20 feet thick, with interbedded thin conglomerate beds. The conglomerate beds are approximately 1 foot thick, and are composed of well rounded pebbles (averaging 1 inch in diameter) of quartz, quartzite and Mathinna sediments. Graded beds 3 to 4 inches thick are often well developed in the coarse sandstones. Festoon cross bedding is characteristically developed and is particularly abundant at 055,744. The cross beds are 2 to 3 feet thick and indicate currents from approximately 300 degrees. Individual laminae are extremely coarse—up to 1 cm. thick, indicating that they were formed in very shallow water.

At, or near the top of the basal sandstone, there are one or more bands of dark grey to black shale, about 3 to 9 inches thick, which contain abundant carbonaceous matter. An extremely carbonaceous band of shale (6 inches thick) in a cliff section at 036,696 has previously been referred to as coal, (Voisey 1938). The basal sandstone is followed (in the area to the south and west of Mt. Elephant) by up to 80 feet of medium to fine sandstone with interbedded mudstone. The amount of mudstone in the formation varies considerably from section to sesction, rarely exceeds 40% of the rock, and is at a maximum in the Gray-Dalmayne area. The sandstones are often finely laminated, showing alterations of sandstone and mudstone or carbonaceous material. The number of alterations varies, and up to 30 per inch occur. Where the rock is predominantly mudstone or shale, the sandstone is often represented as thin flat lenses, about 1 mm. thick. Graphite and mica are very abundant in association with the shales.

Shale partings have been reported in the sandstone in the Harefield and Killymoon bores, and some may be present in the Seymour bore, but Walker (1957) did not report any from Ray's Hill. North of a line through 040,750 and 056,740 the formation is composed entirely of sandstone.

Fifteen feet from the top of section B, there is a pebbly, shaly siltstone, (2 feet thick), which is very similar to the Gray Siltstone and Sandstone. Above this bed, the sandstone contains abundant shale partings and is pebbly in distinct contrast to the rest of the section which lacks pebbles.

The character of the formation changes northwards and at the northern end of Mt. Elephant it rests directly on St. Marys Porphyry or Mathinna Beds. The lower part of the formation in this area consists of very coarse grained sandstone. The coarse sandstones are 20 to 30 feet thick, and grade into medium to fine grained sandstone above. Shale partings are rare, but mica is plentiful, and pebbles are present in small numbers.

The minerology of the sandstones throughout the formation is fairly uniform. The basal sandstones are moderately well sorted, and consist of quartz, quartzite, chert (80 to 90%), feldspar (5%), and rock fragments (5 to 15%). Where matrix is present (as in the basal parts of some graded beds) it is usually of fine sand grade, and consists of quartz and chert particles. Clay or silt size particles seldom constitute more than 5% of the rock.

The upper sandstones are lithologically similar to the basal sandstones, but are uniformly fine grained, the particles averaging 0.2 mm. in diameter. The average grain size throughout the formation decreases upwards from coarse to very coarse sand at the base, to fine sand and very fine sand 50 to 70 feet above the base.

The rocks within this formation include both lithic sandstones and orthoquartzites (Pettijohn 1957), but the majority of sandstones are transitional between the protoquartzite suite and the orthoquartzite suite.

Bedding surfaces are extremely irregular, and individual beds vary in thickness from fine laminations to several feet.

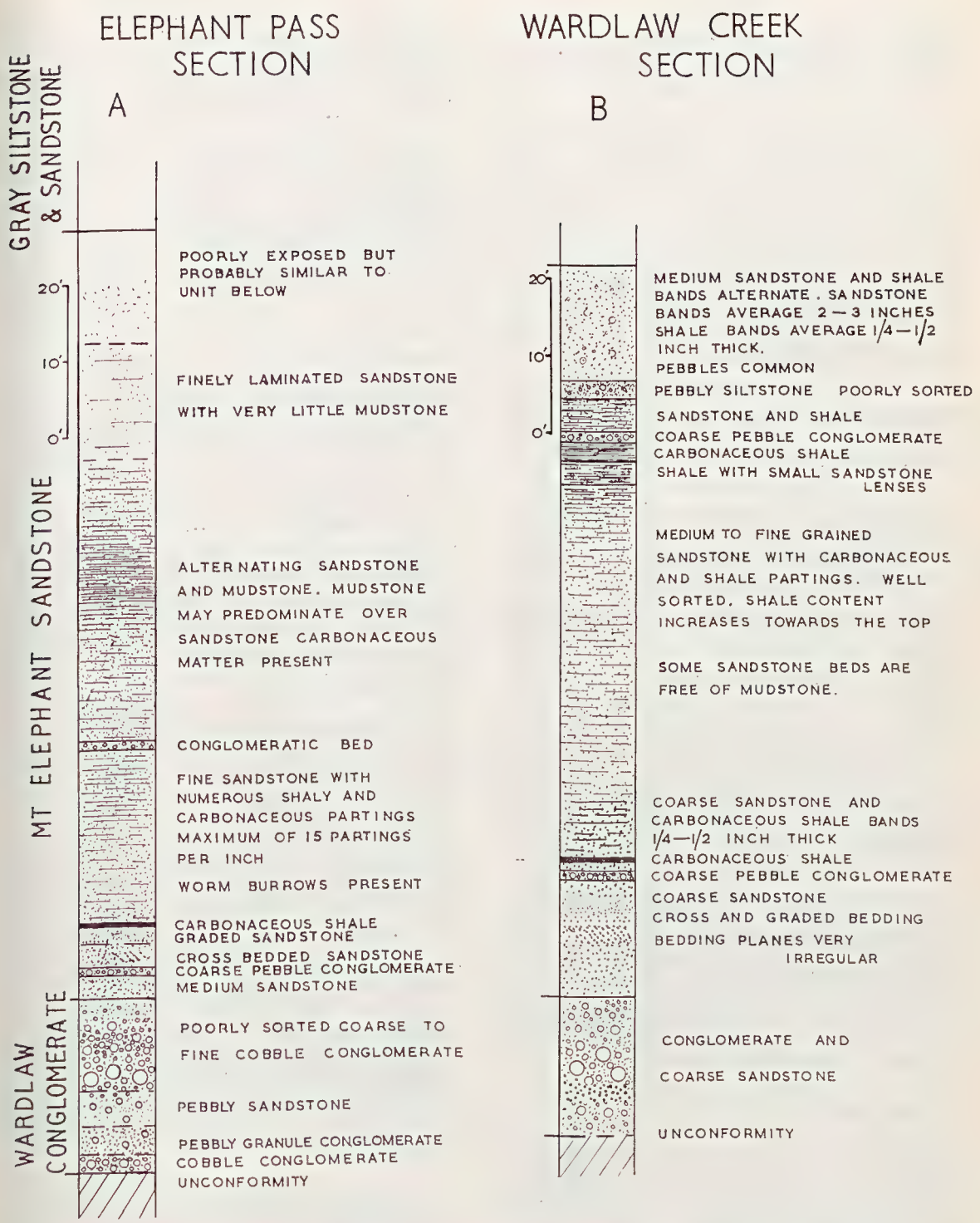

ELEPHANT PASS SECTION
A
WARDLAW CREEK SECTION
B
GRAY SILTSTONE & SANDSTONE
MT ELEPHANT SANDSTONE
WARDLAW CONGLOMERATE
20'
10'
0'
POORLY EXPOSED BUT PROBABLY SIMILAR TO UNIT BELOW
FINELY LAMINATED SANDSTONE
WITH VERY LITTLE MUDSTONE
ALTERNATING SANDSTONE AND MUDSTONE. MUDSTONE MAY PREDOMINATE OVER SANDSTONE CARBONACEOUS MATTER PRESENT
CONGLOMERATIC BED
FINE SANDSTONE WITH NUMEROUS SHALY AND CARBONACEOUS PARTINGS MAXIMUM OF 15 PARTINGS PER INCH
WORM BURROWS PRESENT
CARBONACEOUS SHALE
GRADED SANDSTONE
CROSS BEDDED SANDSTONE
COARSE PEBBLE CONGLOMERATE
MEDIUM SANDSTONE
POORLY SORTED COARSE TO FINE COBBLE CONGLOMERATE
PEBBLY SANDSTONE
PEBBLY GRANULE CONGLOMERATE
COBBLE CONGLOMERATE
UNCONFORMITY
MEDIUM SANDSTONE AND SHALE BANDS ALTERNATE. SANDSTONE BANDS AVERAGE 2—3 INCHES SHALE BANDS AVERAGE 1/4—1/2 INCH THICK.
PEBBLES COMMON
PEBBLY SILTSTONE POORLY SORTED
SANDSTONE AND SHALE
COARSE PEBBLE CONGLOMERATE
CARBONACEOUS SHALE
SHALE WITH SMALL SANDSTONE LENSES
MEDIUM TO FINE GRAINED SANDSTONE WITH CARBONACEOUS AND SHALE PARTINGS. WELL SORTED. SHALE CONTENT INCREASES TOWARDS THE TOP
SOME SANDSTONE BEDS ARE FREE OF MUDSTONE.
COARSE SANDSTONE AND CARBONACEOUS SHALE BANDS 1/4—1/2 INCH THICK
CARBONACEOUS SHALE
COARSE PEBBLE CONGLOMERATE
COARSE SANDSTONE
CROSS AND GRADED BEDDING
BEDDING PLANES VERY IRREGULAR
CONGLOMERATE AND
COARSE SANDSTONE
UNCONFORMITY

FIG. 2.—Sections through the Wardlaw Conglomerate and Mt. Elephant Sandstone at Elephant Pass and Wardlaw Creek.

Gray Siltstone and Sandstone

The Gray Siltstone and Sandstone consists of fossiliferous and poorly sorted fissile siltstone and sandstone. It is 115 feet thick at Elephant Pass and is probably Artinskian in age.

The formation has previously been referred to as part of the Gray Stage (Voisey 1938) which included the Gray Siltstone and Sandstone, and the overlying limestone, mudstone, and sandstone. In hand specimen the rocks are yellow-ochre to grey-brown in colour, and very poorly sorted with abundant pebbles up to 1 cm. in length. The pebbles are well rounded with poor sphericity, and consist of quartz and rock fragments (Mathinna sediments). Rare large fragments of feldspar up to 2 mm. in diameter, flakes of biotite and muscovite, carbonaceous streaks and shell fragments are present. Feldspar is especially abundant in the lower part of the formation (up to 10%).

The siltstones consist mainly of angular grains of quartz, some of which show undulose extinction and contain small grains of apatite and rutile. Muscovite, biotite, calcite, magnetite, plagioclase and clay size fragments are also present. The siltstones contain 5% of sand size particles.

The majority of rocks within this formation are, according to Pettijohn (1957, p. 291), greywackes or greywacke sandstones. Rare graded bedding was noted, the beds grading from medium to fine sand at the base to siltstone at the top.

Marine fossils are present throughout the formation and are abundant in the top 10 to 20 feet. Fragments of brachiopod shells and ostracods occur in the lower beds, while *Polypora, Fenestella,* fenestellids, spiriferids, productids, *Stenopora* and stenoporids are abundant in the upper sandstone and shale beds. A pelecypod from 10 feet below the Berriedale Limestone at 043,702 was identified by Mr. M. R. Banks as *Conocardium australis.* At the northern end of Mt. Elephant a very fossiliferous layer about 2 to 3 inches thick occurs near the base of the formation. The fossils, which include ostracods, stenoporids, fenestellids, brachiopods and small corals, are fragmentary and have abundant pebbles associated with them.

The Gray Siltstone and Sandstone probably corresponds to the Rayner Sandstone and the Nassau Siltstone of southern Tasmania. There is no fossil evidence on this point, except a pelecypod, *Conocardium australis* which occurs in the top of the Gray Siltstone and Sandstone, and in the Nassau Siltstone. The lower parts of the Gray Siltstone and Sandstone and the Raynor Sandstone are very similar in lithology, are extremely poorly sorted, and contain considerable feldspar.

Berriedale Limestone

The Berriedale Limestone has been correlated by Banks (1962) with the Berriedale Limestone in the Hobart area. The Enstone Park limestone of Walker (1957), which occurs at Enstone Park, Falmouth, and at Ray's Hill near St. Marys, is also equivalent to this formation.

The formation consists of alterations of shale, fissile siltstone and limestone, the limestone predominating. It outcrops almost continuously as a fringe to Mt. Elephant, and along the hills south of Gray. A small outcrop of limestone occurs on the western slopes of St. Patricks Head. The limestone often forms cliffs 50 to 60 feet high.

Thirteen chemical analyses of the limestone are given in Hughes (1957) from the Gray area, and calcium carbonate content varies from 54 to 86%, the average being 70%. Percentages of magnesia, alumina and iron are quite small, but the acid insoluble portion varies from 13 to 41%. Nye, in 1926, investigated the limestone deposits in the vicinity of Piccaninny Creek, and six analyses from this area are recorded in Hughes (1957). Average Ca CO_3 is about 75%, but SiO_2 is high, averaging 20%.

The shales and siltstones within the Berriedale Limestone are calcareous, extremely rich in bryozoans and brachiopods, and resemble the uppermost siltstones in the Gray Siltstone and Sandstone. The limestones range from calcirudites to calcilutites, and are seldom pure, with abundant sand grade and larger impurities. Pebbles up to 6 inches in diameter are common on some horizons and consist of quartz, quartzite and subordinate schist and Mathinna sediment.

Gradations of fossil fragment size within one bed were noted at several localities. At 060,717 at least two and probably three graded beds are present within one massive limestone bed. Each graded bed is approximately six inches thick and the fossil fragments range in size from one inch or more in diameter at the base to sand grade and finer at the top.

Limestone generally predominates over shale, but near the base of the formation there may be as much as 16 to 20 feet of highly fossiliferous shale, with only one or two thin limestone bands through it.

Brill (in Banks 1957), measured a section through the limestone in the Elephant Pass area and considered it to be 144 feet thick. The thickest individual limestone bed is approximately six feet thick, and the thickest mudstone bed is five feet thick.

Bryozoans and brachiopods are probably the most abundant fossils and include *Strophalosia, Dielasma, Fenestella, Polypora, Stenopora tasmaniensis, Stenopora sp.,* and *Lyroporella.* Foraminifera, *Calcitornella* (Banks 1957), and large pectens up to eight inches across are common throughout the formation. Corals occur in certain horizons, (*Euryphyllum*) and sponge spicules are abundant. At 023,705 crinoid remains are so numerous that the limestone could be called a crinoidal limestone. Many additional genera and species are recorded by Voisey (1938).

The Berriedale Limestone is about 140 feet thick in the Elephant Pass area, thickens rapidly to the south and thins to the north and west (Fig. 1).

Correlate of Risdon Sandstone

The correlate of the Risdon Sandstone (Banks and Hale 1957) conformably overlies the Berriedale Limestone, and conformably underlies the Ferntree Mudstone. Between the uppermost limestone beds, and the first sandstone bed, there is 12 to 18 inches of mudstone exposed at 023,704 and 042,708. This mudstone is in the same stratigraphical position as the Malbina Siltstone and Sandstone in the Hobart area. Brill (Brill and Hale 1955) identified glauconite in the sandstone beds and correlated these beds with the Risdon Sandstone member of the Ferntree Mudstone at a locality between Mt. Peter and Mt. Paul near Friendly Beaches. On Maria Island (Brill and Hale 1955, Banks 1958) and at Friendly Beaches, the Risdon Sandstone contains a small amount of glauconite.

The sandstone is pebbly throughout and several distinct bands of conglomerate are present. The pebbles vary in size, and range from ½ an inch or less to approximately 12 inches in diameter. At 040,753, the formation is extremely pebbly, the pebbles consisting mainly of metamorphic rocks including banded quartzites, muscovite schists, and conglomerate (similar to the Owen Conglomerate). One specimen shows small scale folding, of a type which is not present in the Mathinna sediments. The nearest place where metamorphic rocks of the type just mentioned outcrop is Beaconsfield.

The sandstones are poorly sorted, and consist of quartz, glauconite, rock fragments, and plagioclase in a fine silt or clay matrix. The percentage of glauconite varies from 15 to 40 per cent. A specimen from 055,720, consisted of quartz 18%, rock fragments and feldspar 6%, glauconite 34%, and fine silt and clay grade material 52%. In other specimens the percentage of fine grained matrix is higher, probably 60-70%. Angular quartz particles, usually with undulose extinction, average 0.2 to 0.3 mm. in diameter, the largest measured being 0.8 mm. and the smallest less than 0.05 mm. The glauconite grains are rounded, and average about 0.15 to 0.2 mm. in diameter. The rock fragments are sub-angular to sub-rounded, consist mainly of chert and slate, and average 0.35 mm. in diameter. The fine matrix consists of quartz and clay with subordinate flakes of muscovite and biotite.

Fossils are not abundant, and are represented by rare brachiopod shells. However, at 061,720, the sandstone contains pectens, brachiopods and gastropods in large numbers, while at 001,720, fenestellids and stenoporids are present.

The base of the sandstone is exposed in several places, but no scouring was observed.

The formation is very irregular in thickness varying from three feet at the Elephant Pass to 60 feet at the northern end of Mt. Elephant. The comparatively large thickness of glauconite rock at the northern end of Mt. Elephant is probably partly equivalent to the Ferntree Mudstone or Malbina Formation.

Ferntree Mudstone

The Ferntree Mudstone (Banks and Hale 1957), conformably overlies the Risdon Sandstone correlate and is overlain, probably disconformably by subgreywacke or quartz sandstone of Triassic age. Voisey (1938) considered the Ferntree Mudstone as part of the Gray Stage. It is 90 feet thick at Elephant Pass, and consists of an alternation of fissile and non-fissile siltstones and mudstones. Hale and Brill (1955) recorded a one inch bed of white montmorillonite bearing clay in the Ferntree Mudstone at Elephant Pass.

In hand specimen the rock is light to dark grey in colour, usually fissile, and appears fine grained, with numerous sand grade and a few larger particles scattered through it. Beds average 9 to 12 inches thick. A thin section showed that the rock consists of mineral and rock fragments up to 0.25 mm. long, in a groundmass of very fine silt and clay. The rock is poorly sorted as all intermediate grades are present, and approximately 10% of the particles are between 0.04, and 0.25 mm. in diameter. Quartz is the dominant mineral, with subordinate rock fragments, feldspar, muscovite, and glauconite. Sericite is well developed in the clay.

Fossils are rare, and consist of poorly preserved brachiopods.

Depositional Environment of the Permian Sediments

Fossils indicate that all sediments except the Mt. Elephant Sandstone, and possibly the Wardlaw Conglomerate are marine. The Mt. Elephant Sandstone contains plant fragments and very rare marine fossils and may be deltaic, the Wardlaw Conglomerate contains no marine fossils, and may be non-marine.

The basal sandstone of the Mt. Elephant Sandstone are coarse grained and are characterised by coarse cross bedding which indicates a very shallow water environment, possibly a beach or shore line. Above the coarse sandstones, there is abundant shale, mudstone and carbonaceous matter associated with the sandstone, and the environment was lacustrine, lagoonal, or deltaic. Marine beds occur in an equivalent position to these a few miles to the north-west. The average grainsize from the Wardlaw Conglomerate through to the top of the Mt. Elephant Sandstone gradually decreases, indicating that the source was being worn down, or the depth of water increasing.

Above the clean sandstones of the Mt. Elephant Sandstone, are the greywacke sandstones and siltstones of the Gray Siltstone and Sandstone. These sediments are extremely poorly sorted, although sorting does improve towards the top of the formation. Graded bedding is suggested in several places, pebbles are common, and fossils are fragmentary and small. The pebbles could be explained by assuming that they were dropped from a floating ice-sheet or ice-bergs on melting, but no striated pebbles were found, and the writer suggests that these sediments are at least in part turbidity current deposits.

The limestones of the Berriedale Limestone are of clastic origin, and usually contain a relatively high percentage of non-calcic material. Graded bedding is present in some limestone bands. Shale beds, rich in fenestellids, stenoporids and

brachiopods occur throughout the Berriedale Limestone. The fossils in the shale beds are unbroken, indicating that the shales were deposited in relatively quiet conditions.

The Risdon Sandstone correlate is extremely pebbly, poorly sorted, and contains pebbles of Precambrian rocks and silicified conglomerates, similar to the Owen Conglomerate. No such sediments occur nearby, and the nearest place that the pebbles could have been derived from is Beaconsfield about 80 miles to the west-north west. Glauconite occurs in the Risdon Sandstone and the thickness of glauconite bearing sediment increases to the northeast. Although previously described as a near shore deposit the writer suggests that the Risdon Sandstone marks a period of instability, and is possibly of turbidity current origin.

The Ferntree Mudstone contains few pebbles, but has a sub-greywacke character in that it contains up to 20% silt and sand grade particles in a clay matrix.

The only evidence to indicate the source area are cross beds in the Mt. Elephant Sandstone, which indicate currents from the west-northwest, or north-west, and the presence of Precambrian pebbles in the Risdon Sandstone.

TRIASSIC SYSTEM

Overlying the Permian System, probably disconformably, are a series of flat lying subgreywacke sandstones, (Pettijohn 1957), with interbedded shales, mudstones, allochthonous coal, and rare conglomerates. Sub-bituminous coal occurs in composite seams with shale or mudstone, the seams ranging from about 1 foot or less to 16 feet thick. Plant remains and silicified wood are commonly associated with the shales (e.g. *Dicroidium, Cladophlebis australis, Johnstonia* &c.), and indicate a Triassic age, Banks 1952). All the rocks within this system have been mapped as one unit (New Town Coal Measures of Carey and Hills 1949, Feldspathic Sandstone of Banks (1962), and will be referred to as Feldspathic Sandstone. The sandstones usually outcrop as small discontinuous cliffs about 30 to 50 feet high. Dips are always shallow (between 0 and 4 degrees), and Keid (Hills *et al* 1922), reported that the coal seams in the Dalmayne Colliery dip in a southerly direction at a low angle. The total thickness of sediment varies between 500 and 750 feet, depending on the position in which the Jurassic dolerite was intruded.

At the base of the Triassic System around Mt. Elephant and just south of Gray, there is a granule conglomerate similar to the Sister's Granule Conglomerate at Ray's Hill (Walker 1957). This granule conglomerate is discontinuous and varies rapidly in thickness, e.g., may vary from 40 feet thick to zero in less than 100 yards. It does not appear to be present in the Piccaninny Point square. Graded bedding is common, the graded beds varying from granule conglomerate at the base, to medium coarse sand at the top. The graded beds are never more than 6 inches thick, and are extremely limited in lateral extent. No medium or coarse conglomerates are associated with the basal beds.

The so-called feldspathic sandstones consist of a regular series of subgreywacke sandstone, interbedded with variously coloured shales. Up to seven coal seams are represented, the lowest one occurring within 20 feet of the base of the system at 684,027. Bedding is not well developed, and on weathering, the sandstone becomes grey to buff coloured, and numerous horizontal partings, (about 1 cm. apart) giving it a laminated appearance, tend to become developed. Thinly bedded alterations of sandstone, shale, or carbonaceous matter are quite common.

The rocks are moderately even grained, of fine to medium sand grade, and consist essentially of rock fragments and quartz. Feldspar occurs as twinned plagioclase approximately 0.15 to 0.2 mm. in diameter, (probably andesine). Biotite and muscovite (1 to 2%) occur as long flakes up to 1 mm. long. Quartz particles (15 to 20%, including quartzite and chert) are usually angular to sub-angular, and average 0.2 mm. in diameter. Quartzite particles frequently show evidence of strong deformation, and the quartz fragments exhibit undulose extinction. Rock fragments, excluding quartzite and chert, comprise about 70 to 80% of the rock, and include mudstone, shale, slate, schist, and igneous rock fragments. Some of the fragments have been extensively sericitised. The pieces of fine grained igneous rock consist of interlocking laths of plagioclase (about 0.25 to 0.3 mm.).

The most important fact arising from this description is that these sandstones are not feldspathic sandstones according to any modern classification. Pettijohn (1957), classifies these rocks as lithic sandstones, within the subgreywacke subdivision.

Clay pellets, a few inches in length, and clay lenses up to several feet in length, are extremely common throughout the sandstone. Similar lenses and streaks of carbonaceous matter are also common. Just south of this area at Seymour, four bores have been drilled through the Triassic beds (Hills *et al* 1922), and the ratio of shale to sandstone in the cores is approximately 0.65.

Several thin beds of pebble conglomerate one to three feet thick occur south of Gray. No pebbles of definite Permian age occur in these conglomerates. Cross bedding occurs in a few localities, but is poorly exposed, and no reliable current directions were obtained.

QUATERNARY SYSTEM

Dolerite Talus

Dolerite talus is extensive around St. Patrick's Head, Mt. Elephant, and on the slopes of the hills flanking the coast south of Gray. The scree is up to 200 feet thick, and consists of dolerite pebbles, cobbles, and boulders up to 15 feet in diameter, in a clay matrix. Fragments of feldspathic sandstone are rare.

Around Mt. Elephant, the scree cover extends down to 1300 feet above sea level, i.e., to the top of the Permian or just below it. The cover is not complete, and several large areas of Triassic sedi-

ment outcrop within it, often as small cliffs. The talus has been interpreted by Everard (in Hughes 1957), as small sills, but this seems unlikely as wherever the underlying rock is exposed (e.g. in creeks), it consists of Triassic sediment. At the present, with only 200 feet of dolerite on the top of Mt. Elephant there is very little scree forming, and the talus slopes are being dissected and eroded.

South of Gray, the dolerite talus is very extensive, particularly in the Dalmayne area. At 057,677, the talus is only 200 feet above sea level, and extends for 1400 to 1500 feet to the dolerite in situ at approximately 1600 feet above sea level. South of Piccaninny Point, the talus extends to sea level, but here the dolerite occurs at less than 1000 feet above sea level. The talus slopes are now fairly stable and have a thick cover of vegetation.

IGNEOUS GEOLOGY

ST. MARYS PORPHYRY

The St. Marys Porphyry has been described by W. N. Benson for Twelvetrees (1911), and by Walker (1957). Twelvetrees referred to it as a granitic porphyry, but Walter rejected this name in favour of porphyrite. The writer considers the rock to be a biotite, hypersthene, adamellite porphyry.

The St. Marys Porphyry is hard, brittle, blue-grey to light-grey, and varies from strongly to weakly porphyritic. Phenocrysts of plagioclase, quartz and ferromagnesian minerals are usually visible in the hand specimen. The porphyry produced only low grade thermal metamorphism in the Mathinna Beds.

The porphyry is a shallowly dipping intrusion, and underlies an area of at least 33 square miles, including the northern and eastern parts of the Mt. Elephant square. The base of the intrusion is exposed west of Falmouth, and has been described by Walker (1957), who considered that the floor of the mass dipped south at an angle of approximately 15 degrees. In the Mt. Elephant square the top of the intrusion is exposed at 002,792, and 004,777. At 002,792 the top of the porphyry dips to 210 degrees at 10 to 15 degrees, and at 004,777, dips in a south-westerly direction at 25 to 30 degrees.

The thickness of the St. Marys Porphyry is difficult to estimate, but is at least 800 feet (equivalent to a volume of 5 cubic miles), and may be as much as 5000 feet (which would give a volume of at least 32 cubic miles). There is no evidence of multiple intrusion. The most probable thickness is 4000 feet. This figure is obtained after allowing for faulting, by assuming that the base of the intrusion near Falmouth (Walker 1957), and the top at St. Marys both dip in a southerly or south-westerly direction at 15 degrees.

The porphyry was intruded after the folding of the Mathinna Beds, but the structure of the sediments did not influence the form of the intrusion. The porphyry is older than, (not younger, as Walker suggested) and has been intruded and metamorphosed by adamellite east of Mt. Elephant.

Careful examination of the main rock mass has not revealed any preferred orientation, although microscopic flow structures are present at the margins.

A chemical analysis of the St. Marys Porphyry has been published in Spry and Banks (1962).

Rocks similar to the St. Marys Porphyry have been described from Victoria and New South Wales. David (1950) refers to a large mass of hypersthene bearing porphyrite in the Strathbogie area of Victoria, but later writers (White 1953), have considered this rock as a dacite. A similar hypersthene dacite has been described by Edwards (1955), from the Dandenong Ranges, and a quartz, biotite, hypersthene rhyodacite has been described by Thomas (1947), from the Cerberean Ranges. This last rock contains rare phenocrysts of orthoclase, and appears to be very similar to the St. Marys Porphyry.

Petrology

The St. Marys Porphyry is remarkably homogeneous and is always porphyritic, although where the groundmass is coarse the porphyritic character tends to be obscured to some degree. The grainsize of the groundmass varies systematically throughout the intrusion from cryptocrystalline, in and near the chilled border region, to fine grained (0.1 mm.) in the centre. Where the groundmass is relatively coarse, it is difficult to assign an upper limit in size to it, because there is a complete range between the groundmass and the phenocrysts.

No evidence for differentiation was found from a study of thin sections from various parts of the intrusion, or from a traverse up the road from Four Mile Creek to Irish Town, through approximately 1000 feet of porphyry (from 048,761 to 073,768). The data obtained from these thin sections is summarised in Table 1. Specimen A came from 1200 feet above sea level and within 200 feet of the top of the intrusion. The average grainsize of the groundmass increases downwards to a point 800 to 900 feet below the top, where it begins to decrease again. This may mean that specimen D is from near the middle of the intrusion.

Modal analyses were carried out on 24 thin sections, using an intergrating stage, and the average mineralogical composition calculated. Quartz (21.4%), plagioclase (25.6%), potash feldspar (about 1%), biotite (8.4%), and hypersthene (5.8%) occur as phenocrysts in a crystalline groundmass which comprises 37.9% of the rock.

Several slides in which the groundmass is comparatively coarse, were stained with sodium cobaltinitrite (Chayes 1952), to enable potash feldspar to be readily distinguished. Modal analyses showed that about 57% of the groundmass is potash feldspar, 38% quartz, and 5% plagioclase. Thus the approximate mineralogical composition of the rock is—

	Phenocrysts	Groundmass	Total
Quartz	21%	14%	35%
Plagioclase	26%	2%	28%
Potash Feldspar	1%	22%	23%
Biotite	8%	....	8%
Hypersthene	6%	....	6%

Quartz phenocrysts occur as clear, irregular grains, often extremely corroded and poikilitic with pseudo-inclusions or inclusions of groundmass. The largest quartz phenocroyst measured was 6 mm. by 4 mm., but generally the maximum size is approxi-

mately 3 to 4 mm., and the average size about 1.5 mm.

Plagioclase phenocrysts are euhedral or subhedral, often slightly corroded, and sometimes appear to have been derived from larger phenocrysts by shattering. They are smaller than the quartz phenocrysts and average less than 1 mm. in diameter. The average composition of the plagioclase (from carlsbad-albite and albite laws) is Ab50, andesine-labradorite, and in zoned crystals the compositional variation is usually from Ab45 to Ab60. The fragments of plagioclase of groundmass size, (i.e., about 0.1 mm.), are more acid and vary from acid-andesine to andesine.

Potash Feldspar phenocrysts are comparatively rare, and are generally clear, undecomposed, and slightly rounded by corrosion. They are free from twinning, average about 0.4 to 0.6 mm. long, and are rarely greater than 1 mm. long. The phenocrysts differ in composition from the potash feldspar of the groundmass. Whereas the feldspar of the groundmass is probably orthoclase, the phenocrysts are sanidine and anorthoclase. The optic angle (2V), of the potash feldspar phenocrysts varied from 28 to 62 degrees.

Hypersthene, light olive grey in colour, forms euhedral to anhedral crystals averaging 0.6 to 0.7 mm. in diameter. The grains are cracked and inclusions of groundmass and plagioclase occur. Reaction rims of amphibole are common but the characteristic green-pink pleochroism is not always present. Hypersthene varies from 3 to 9.5% of the rock, and there is a tendency for the percentage to decrease towards the middle of the intrusion. Where hypersthene is lacking, quartz is generally relatively abundant, and vice versa.

Biotite forms between 5.5 and 12% of the rock and occurs in fresh euhedral to subhedral flakes. The flakes are variable in size, ranging from approximately 2 mm. to 0.1 mm. in length. In places the cleavage lamellae have been forced apart by the groundmass. Zircon crystals are present in the biotite.

The groundmass consists of quartz, potash feldspar (probably orthoclase), and plagioclase, in the proportion 7:12:1. It varies in grainsize from 0.009 mm. in the contact zone to 0.1 mm. in the central part of the intrusion.

The plagioclase of the groundmass is acid andesine to andesine, and is generally present in zoned, euhedral crystals. The quartz grains are colourless, and the potash feldspar fills the interstices and was the last mineral to crystallise.

Magnetite, apatite, zircon and topaz occur as accessory minerals.

Contact Zone.

At the contact, quartz phenocrysts comprise 18% plagioclase phenocrysts 11%, ferromagnesian minerals and chlorite 4%, and the groundmass 67% of the porphyry. There are abundant small quartz particles about 0.1 mm. in diameter, which are derived from the greywacke sandstones of the Mathinna Beds. The larger phenocrysts of quartz are well formed with fairly round edges, and are up to 4 mm. long. Plagioclase is not abundant, and is confined to small crystals less than 1 mm. long. The groundmass is very fine grained (about 0.009 mm.), and contains abundant chlorite which is aligned to give a flow structure. This microscopic flow structure is generally sub-parallel to the contact but diverges around and encircles the larger phenocrysts.

A specimen 18 inches from the contact consisted of phenocrysts of plagioclase (19%), quartz (10%), anorthoclase (7%), and ferromagnesian minerals (6%), in a cryptocrystalline groundmass (58%). Anorthoclase occurs as anhedral to rounded crystals which are often slightly cloudy. The largest crystal measured was 4 mm. by 2.5 mm. No sanidine was identified in the contact zone. The plagioclase and quartz grains are badly cracked, and the plagioclase is commonly partly sericitised, particularly in the cores. The quartz grains are up to 2 mm. long, have rounded edges, and show undulose extinction. Some of the grains are composed of a mosaic of quartz particles, resembling strongly deformed quartzite. Biotite is not abundantly developed as phenocrysts, but it does occur in small crystals up to 0.8 mm. long. Generally the ferromagnesian minerals have been altered to chlorite.

A little further from the contact the phenocrysts of quartz and plagioclase begin to break up. A specimen 20 feet from the contact shows quartz phenocrysts shattered into several pieces with groundmass filling the cracks and pushing the pieces apart. This rock is composed of phenocrysts of quartz (19%), plagioclase (27%), chlorite (18%) in a cryptocrystalline groundmass. The groundmass varies from 0.005 to 0.01 mm. in diameter, and there is a poorly developed flow structure present.

TABLE 1.

	A	B	C	D	E	F
Height above sea level	1200	980	840	640	380	180
Locality	004, 761	652, 761	057, 762	061, 762	066, 762	072, 768
Plagioclase (%)	23.4	28.8	25.6	22.1	27.8	20.6
Composition	Ab46-Ab64	Ab44-Ab66	Ab50-Ab60	Ab44-Ab56	Ab40-Ab66	Ab50-Ab66
Maximum Size (mm.)	2.3	2.5	2.0	2.0	13.0	2.0
Average Size (mm.)	0.9	1.0	0.9	0.8	0.8	1.0
Quartz (%)	19.8	22.8	21.1	19.5	23.8	19.2
Maximum Size (mm.)	2.7	5.0	6.0	2.0	4.0	4.5
Average Size (mm.)	1.0	1.0	1.5-2.0	0.9	1.0	1.5
Biotite (%)	11.0	6.1	10.7	11.9	8.2	7.4
Maximum Size (mm.)	1.0	1.0	2.2	2.0	2.0	1.5
Average Size (mm.)	0.6	0.55	0.5	0.6	0.7	0.6
Hypersthene (%)	6.2	4.1	6.5	7.0	3.0	9.3
Maximum Size (mm.)	1.3	1.0	2.0	1.3	1.6	2.3
Average Size (mm.)	0.8	0.5	0.65	0.7	....	0.8
Groundmass (%)	40.5	38.3	36.1	39.5	37.4	43.5
Maximum Size (mm.)	0.3	0.3	0.35	0.4	0.3	0.45
Average Size (mm.)	0.045	0.06	0.07	0.08	0.06	0.065
Potash Feldspar Phenocrysts	Present	Present	Present	Present	Present	Present
Maximum Size (mm.)	0.85	0.50	0.65	0.95	0.65	0.8

Discussion

From the above petrological evidence, there is no doubt that the magma was partly crystallised (about 30%) at depth, before it was emplaced in the Mathinna Beds. The fractured and fragmentary nature of many phenocrysts, especially plagioclase and quartz, and the ruptured twin lamellae and bent biotite flakes, all indicate that strains were imposed on these mineral grains during the process of magma emplacement.

The corroded nature of the feldspar, and the presence of corrosion embayments in the quartz phenocrysts, indicates that the phenocrysts were metastable after intrusion. Rapid cooling forestalled complete reabsorbtion of any mineral, although the relatively high concentration of anorthoclase phenocrysts in the contact zone indicates that most of the potash feldspar phenocrysts were absorbed in the main mass of porphyry. The fact that the potash feldspar phenocrysts are much larger in the contact zone (about 3 mm. in diameter), than in the more central parts of the intrusion, (always less than 1 mm. in diameter), also supports this conclusion.

The presence of sanidine and anorthoclase indicates that the magma was at a high temperature when these phenocrysts were formed. The unaltered state of the anorthoclase in the contact zones indicates that the magma was probably still at a high temperature when intruded.

Walker's original name of porphyrite has been discarded in favour of porphyry. Porphyrite is commonly used for acid rocks rich in plagioclase, but deficient in potash feldspar. Porphyry (Johannsen, p. 276, 1939), is generally used for rocks showing larger crystals in a finer groundmass. Thus as the St. Marys Porphyry contains approximately equal amounts of potash and plagioclase feldspar and is porphyritic, adamellite porphyry is considered a more suitable name than porphyrite.

PICCANINNY CREEK ADAMELLITE

The adamellite and associated granitic rocks (Middle or Upper Devonian) form an elongated stock, the axis of which trends 353 degrees. It outcrops over an area of slightly more than 9 square miles, and is partly obscured by Permian sediments to the north-west, and by alluvium and the sea to the south-east. It intrudes the Mathinna Beds and St. Marys Porphyry with sharp transgressive contacts. South of Wardlaw Creek the contact dips 60 degrees west. The best exposed contacts with the Mathinna Beds occur at Piccaninny Point, and in the lower part of the Elephant Pass section of the Tasman Highway.

The main mass is an adamellite, but granodioritic variations occur along the northern boundary of the mass and at Piccaninny Point. No porphyritic, or muscovite bearing varieties occur. Exposure is poor in the southern part of the stock, where the adamellite forms low hills and the coastal plain, but improves to the north where it rises to over 1000 feet above sea level and has been deeply dissected by small streams.

Walker (1957), mapped a similar granitic rock in the Scamander-St. Helens area, but named it a quartz monzonite. The similarity in appearance, grainsize, texture and mineralogy of the quartz monzonite and adamellite indicates that they are probably equivalent, and part of the same batholith which plunges beneath the St. Marys Porphyry from the north and south. Outcrop to the south of Piccaninny Point is poor, but a granodiorite similar to that at Piccaninny Point occurs on Long Point

at Seymour. Further south, around Bicheno, a porphyritic granitic rock, with large phenocrysts of feldspar, averaging 2 to 3 inches long crops out.

Aplitic rocks (quartz 35%, orthoclase 60%, plagioclase 5%), are very common, and occur as small dykes cutting both the adamellite and surrounding Mathinna Beds. They are confined to the border regions of the adamellite, and strike in an east-west direction. Pegmatites are present as dykes in the quarry at 069,674, and as irregularly shaped bodies north of there in a road cutting on the Tasman Highway.

A basic dyke occurs in a road cutting on the Tasman Highway at 057,679. It is about 3 feet wide, dark coloured, vertical, and strikes approximately east-west. The rock is badly weathered, has an intergranular to slightly micro-porphyritic texture and consists of plagioclase (75%), clino-pyroxene (5%), and mesostasis (20%). The plagioclase (Ab50) occurs in laths averaging 0.4 mm. long, and is often corroded and slightly zoned. One or two euhedral phenocrysts greater than 2 mm. long are present. Clino-pyroxene forms small grains averaging 0.1 to 0.2 mm., with some larger crystals up to 0.4 to 0.6 mm. long. The mesostasis consists of fine pyroxene and untwinned feldspar together with abundant iron oxide. Apatite is comparatively abundant (approximately 1% of the rock) and forms euhedral crystals up to 0.6 mm. long.

Contact metamorphism is of low grade, except in one or two places that will be discussed later, (Piccaninny Point, and part of the adamellite—St. Marys Porphyry Contact). Generally the only metamorphic effect that the adamellite had on the Mathinna Beds was a slight recrystallisation and induration and the development of minor biotite.

Petrology

The main mass of granitic rock is an adamellite with approximately equal amounts of potash and plagioclase feldspar. In hand specimen it is a light coloured, medium even grained rock, with visible quartz, feldspar and biotite. It is mineralogically uniform, and there are no porphyritic, or microgranitic variations.

The mineralogical composition of the rock was determined by modal analyses of both thin and polished sections. Both methods yielded approximately the same percentage, and all counts were averaged to find the mineralogical composition to the nearest percent ÷ quartz 34%, potash feldspar 33%, plagioclase 28%, biotite 4%, hornblende 1%.

Quartz anhedra are often intergrown with potash feldspar, or form sutured mosaics, the component grains of which are characterised by undulose extinction. Undulose extinction is fairly common among the normal ragged anhedra, and the quartz content of the rock varies from 29% to 39%. The average grain size varies from 1 to 1.5 mm., with grains up to 5 or 6 mm. across.

Potash feldspar was the last mineral to crystallise and form anhedra which enclose all other minerals. It forms between 30 and 36% of the rock, and is untwinned orthoclase, or more rarely microperthite. The grains are unaltered, and average 2 to 3 mm. in diameter, ranging up to 6 to 8 mm. long.

Plagioclase occurs in slightly altered, euhedral to subhedral grains and comprises between 24 and 36% of the rock. Slight sericitisation is common, particularly in the cores of zoned crystals. The composition is andesine (approximately Ab60), varying to oligoclase (approximately Ab80) in zoned crystals. The average grain size of the plagioclase is 1.2 mm., and the largest crystal measured was 4.5 by 4.0 mm.

Biotite is the only mafic mineral of any importance in the adamellite, although rare crystals of hornblende are present. It constitutes approximately 4% of the rock, and is generally unaltered although chloritisation has been noted in places. The flakes are small and less than 1 mm. in diameter. Hornblende occurs in aggregates of small crystals each less than 1 mm. long; however, the size of the aggregate may reach several millimetres long.

Small grains of sphene, zircon, apatite and magnetite are present, but muscovite is completely absent.

A more basic, or biotite-hornblende-adamellite, apparently formed by contamination of the magma with Mathinna sediments, occurs along the western boundary of the stock. A specimen from 058,676, consists of quartz 33%, potash feldspar 24%, plagioclase 29%, biotite 9%, hornblende 5%. The biotite and hornblende are present mainly at the expense of orthoclase. The grain size and the quartz and orthoclase are similar to that of the main adamellite. The composition of plagioclase is andesine and in zoned crystals varies from Ab55 to Ab70. Biotite is present in relatively large crystals up to 2 mm. long, and hornblende occurs in large crystals up to 4 mm. long. The contaminated zone is approximately 50 yards wide.

A fine grained porphyritic adamellite sill is exposed in a road cutting on the Tasman Highway at 056,679. The mineralogical composition is: quartz 34%, orthoclase 31%, plagioclase 31%, biotite 4%. The plagioclase phenocrysts are andesine, are slightly sericitised, and occasionally contain small inclusions of quartz. Quartz phenocrysts are not as abundant, and average 1 mm. in diameter varying to a maximum of 4.5 mm. The groundmass consists of small rounded quartz particles (0.1 to 0.3 mm. in diameter), set in orthoclase "cement".

Granodiorite (at contact with the St. Marys Porphyry)

A small area of granodiorite occurs at the contact of the granitic rocks with the St. Marys Porphyry (087,720). The granodiorite is even-grained and much darker than the adamellite. It consists of anhedral quartz (26%), euhedral to subhedral plagioclase 47.5%, biotite 13%, hornblende 9%, and a little orthoclase 4.5%. Thus the rock approaches a trondhjemite, or tonalite (depending on classification) in composition. The texture is slightly micro-porphyritic, with large phenocrysts of plagioclase up to 5 mm. long. The quartz is generally

unstrained, and averages 1 mm. in diameter. The plagioclase crystals average 1.5 mm. in diameter, and vary from 5 mm. to 0.1 mm. Zoning is common, especially in the larger crystals. The composition of the plagioclase except for the few large crystals which are more sodic, (basic oligoclase, Ab70) is andesine Ab56. Sericitisation is common in the large crystals, particularly in the more basic cores. Biotite and hornblende both form euhedral to subhedral crystals that average about 1 mm. in length. Apatite is an important accessory, and is much more abundant than in the adamellite.

At the boundary of the granodiorite and the adamellite, the rock contains approximately 30% ferrogmanesian minerals, (biotite and hornblende). Orthoclase is more abundant, and forms 10 to 20% of the rock. Plagioclase occurs in two distinct sizes; anhedral crystals greater than 1 mm. in diameter, and small lath shaped crystals which are scattered haphazardly throughout all the other minerals, except the hornblende, (i.e., quartz, orthoclase, and biotite). This gives the rock a very distinctive texture. The composition of both large and small crystals of plagioclase is Ab 56. The quartz is clear and unstrained, and twinning is common in the hornblende. The biotite flakes are irregular, and have a sub-ophitic relationship with the plagioclase. The unusual texture and relatively large amount of orthoclase, may indicate that this rock is an adamellite that has been metamorphosed by the granodiorite.

Contact Metamorphism of the St. Marys Porphyry.

The granitic stock is a later body than the St. Marys Porphyry, and has intruded and metamorphosed the porphyry. The contact and metamorphosed porphyry are well exposed in a small creek at 087,721 where numerous xenoliths of porphyry are present in the granitic rock. The porphyry near the contact shows a weak schistosity, a lightening in colour, and a marked increase in the amount of visible biotite. The metamorphosed porphyry is fine, even-grained, and consists of quartz, plagioclase, biotite, clinopyroxene, hornblende, and a little orthoclase. Mineral percentages and sizes vary considerably.

Quartz is present in clear, anhedral grains which are very variable in size. In some cases the quartz has a poikilitic appearance with inclusions of subhedral or euhedral plagioclase, pyroxene and biotite. Some of the quartz grains have recrystallised in optical continuity, forming large areas of granular quartz up to 10 mm. across.

Plagioclase occurs in euhedral to subhedral or lath shaped crystals that vary in size from less than 0.1 mm. to large crystals 5 mm. in width. Frequently the larger grains are composite, consisting of several plagioclase crystals, each of which are about 2 mm. in diameter. They have corroded and irregular edges, but presumably their large size has prevented them from being altered. The composition of the large plagioclase crystals is Ab48, but the smaller lath shaped crystals are more calcic with a composition of Ab42.

Orthoclase is present interstitially, but only in small amounts, and never exceeds 10%. It is generally clear and undecomposed, and is most easily recognised by using staining techniques (Chayes 1952).

Hypersthene and a clinopyroxene (diopside?) are present. The clinopyroxene occurs in small granules, which average 0.1 to 0.2 mm. in diameter, and is much more abundant than the hypersthene. The clinopyroxene is particularly abundant right at the contact, and in some specimens it comprises 10 to 20% of the rock. The amount of clinopyroxene decreases rapidly away from the contact. The hypersthene, which occurred in the original rock as phenocrysts, has been partly or completely altered to hornblende and biotite. In some cases hypersthene is comparatively abundant, and occurs as residual cores up to 0.8 mm. long, in hornblende.

Apatite is present, often in relatively large amounts, (up to 1 to 2%).

During contact metamorphism the first effect of heating was to stimulate a reaction between the hypersthene phenocrysts and the orthoclase of the groundmass, to yield biotite. With more intense heating CaO became available from the plagioclase, and reacted with the biotite to form hornblende (Edwards 1955). The presence of regenerated pyroxene in the contact zone indicates that metamorphism is high grade, and the rocks belong to the Pyroxene Hornfels facies. Of the original rock the quartz, and most of the plagioclase has been recrystallised, only the larger phenocrysts of plagioclase persisting.

A xenolith several feet wide, with a high lime content, was found in the granodiorite near the St. Marys Porphyry contact. The rock is light-grey to blue-grey in colour, and consists of wollastonite, quartz, diopside and a little potash feldspar.

PICCANINNY POINT CONTACT

The contact between the Mathinna Beds and granodiorite is well exposed at Piccaninny Point. The sediments are extremely indurated and veined, and locally, high grade metamorphic temperatures were reached (pyroxene hornfels facies). The contact is partly concordant and dips west at approximately 80 degrees.

Small veins of quartz, aplite, pegmatite and granodiorite 3 to 4 inches thick, are common, and some contain tourmaline. Ptygmatic folding is present, and was noted particularly where a vein cuts across the bedding of the sediments. Veins which are parallel to the bedding are usually straight, although some show a tendency to develop pinch and swell structure. The veins have clear cut boundaries, and appear to have been intruded in a liquid or semi-liquid state. Little granitisation has taken place at the boundaries of the veins (about 1 to 2 mm.) and some have been extensively sheared. A possible explanation of the ptygmatic structures might be sought in a local internal movement of the sediment parallel to the bedding before complete consolidation of the vein material. Such movement would deform the veins cutting across the bedding, but would retain the linear nature, although causing some pinch and swell, of the parallel veins. The sheared nature of some veins also supports this idea.

A well marked parallelism of ferromagnesian minerals and xenoliths, trending between 165 and 175 degrees, occurs within the granitic rocks at Piccaninny Point. Petrofabric analyses have been carried out on several specimens (see page 41). Xenoliths are abundant, and are elongated parallel to the lineation in the granodiorite. They are usually rounded and occur in all stages of assimilation.

Small transcurrent faults, cutting both sediments and granodiorite are common and show horizontal movements of a few inches, to three feet. Fourteen trends were measured, and can be divided into two groups. Those with dextral movement trend between 112 and 125 degrees, and those with sinistral movement trend between 65 and 100 degrees. It can be demonstrated in at least one case that they are conjugate shears. Similar transcurrent faults occur at Long Point, Seymour, about four miles south of Piccaninny Point.

Several aplite dykes approximately one foot thick and trending 100 degrees, cut both the sediments and granodiorite at the southern end of Piccaninny Point.

Petrology

The main mass of granitic rock at Piccaninny Point is biotite, hornblende granodiorite, which has an average composition of : quartz 33%, potash feldspar 20%, plagioclase, 32%, biotite 8.5%, hornblende 6.5%.

In hand specimen the rock appears slightly platy, and is considerably darker than the normal adamellite. The texture is sometimes slightly microporphyritic.

Quartz varies from 28 to 40% of the rock. The quartz grains make up streaky, sutured mosaics, the component grains of which are all characterised by undulose extinction. Individual grains are small (average 0.3 mm.), and are never more than 1 mm. long, although the mosaic patches of sheared quartz are up to 4 or 5 mm. long i.e., about the same maximum size of the undeformed quartz particles in the adamellite.

Plagioclase varies from 27 to 36% of the rock, and occurs in euhedral to subhedral grains averaging 1 to 2 mm. in diameter. The composition is andesine, but in zoned crystals, the outer layers are acid andesine or basic oligoclase.

Orthoclase varies from 11 to 25% of the rock, It is always anhedral, clear and unaltered, and was the last mineral to finish crystallising.

Biotite varies from 6 to 13% of the rock. The maximum grain size is about 2 mm., and the average grainsize 0.7 mm. A few flakes are bent.

Hornblende occurs in euhedral to subhedral twinned crystals or aggregates of crystals, and varies from 4 to 9% of the rock. The average length of the crystals is about 1 mm., with some up to 3 or 4 mm.

In addition to the parallelism in the granodiorite, there is a well marked compositional banding along some parts of the contact. The bands are best exposed in a sill, a few yards away from the main intrusion. The mineralogical composition of the bands sampled are as follows:—

	(1)	(2)	(3)
Quartz	30.8%	34.4%	34.5%
Potash Feldspar	14.7%	22.9%	minor
Plagioclase	30.6%	33.1%	34.7%
Biotite	14.6%	6.6%	22.0%
Hornblende	9.4%	2.9%	8.8%

The bands trend approximately north-south, parallel to the contact, specimen one being nearest the contact, specimen two next, and specimen three farthest away. Each band is 2 to 3 feet thick. The percentages of quartz and plagioclase are fairly constant, but both the ferromagnesian minerals and orthoclase vary considerably. The first two bands could be classified as biotite-hornblende-granodiorite and biotite-granodiorite respectively, but the third band is a biotite-hornblende-tonalite (quartz-diorite), or a biotite-hornblende trondhjemite. The individual minerals are very similar to those already described for the main granodiorite. The textures however, are usually micro-porphyritic, with large phenocrysts of plagioclase up to 6 mm. long. The plagioclase is andesine and the quartz particles are always strained and shattered.

Thermal Metamorphism

The sediments at Piccaninny Point are more highly metamorphosed than the Mathinna Beds at the adamellite contact. Elsewhere the Mathinna Beds have been recrystallised, deformed and extensively veined, but generally the metamorphism is not high grade, and most of the sediments can be classified within the albite-epidote hornfels facies (Turner and Verhoogen 1951).

At Piccaninny Point the metamorphosed sediments are medium to fine grained, and contain biotite, quartz, microcline, cordierite and lesser amounts of muscovite, epidote, albite and chlorite. Biotite flakes are very variable in size, quartz particles are strained, and the potash feldspar and cordierite are usually slightly turbid. Within one slide the grainsize may change abruptly from medium grain, with a mineralogical composition of quartz, microcline, cordierite and biotite, to very fine grained with a mineralogical composition of quartz, biotite, muscovite and chlorite.

In several places a small zone at the contact, less than one inch thick, contains sillimanite and corundum. Abundant biotite and microcline and lesser amounts of quartz, cordierite, and muscovite also occur. Sillimanite is relatively abundant, and occurs as slender prismatic crystals which generally form a felted mass of fibres. Corundum forms 3 to 5% of the rock and occurs in large crystals up to 2 mm. in diameter. Microcline occurs as large xenoblastic crystals up to 3 or 4 mm. long and biotite as flakes averaging 0.5 to 0.7 mm. long.

At the contacts of several small granite veins small crystals of a green spinel are developed, usually surrounded by a reaction ring of muscovite, chlorite, and zoisite. Rare crystals of epidote are also present.

The thermal metamorphism at Piccaninny Point, and the lack of metamorphism elsewhere indicates that the Piccaninny Point area was probably a "high spot" near the roof of the adamellite stock, in which the vapours and fluids of the magma were concentrated.

Petrofabric Analysis

A pronounced megascopic lineation, trending 165 to 175 degrees is present throughout the granodiorite at Piccaninny Point.

Petrofabric analyses were carried out on selected, oriented specimens from the main mass of granodiorite, compositional bands near the sediment-granodiorite contact and a granodiorite sill. Sections were cut perpendicular and parallel to the lineation and the poles to biotite cleavage flakes (001 cleavage) and the optic axes of quartz crystals were plotted on an equal area net (using the lower hemisphere) and contoured.

The analysis of the main granodiorite mass using biotite cleavage flakes is shown in figure 3A. The

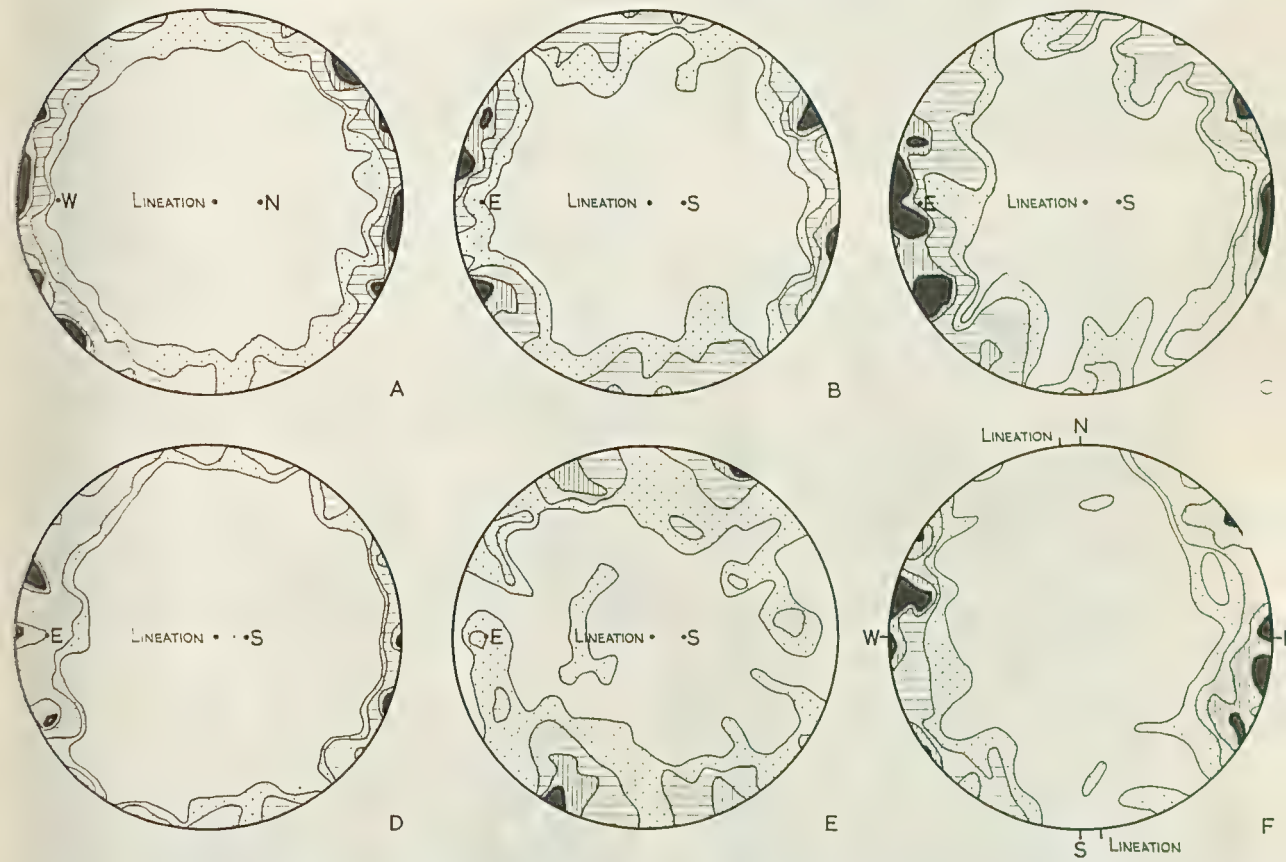


FIG. 3.—Biotite and quartz orientation diagrams (equal area projections). Contour interval—6%, 5%, 3%, and 1%.
3A Poles to 250 biotite flakes, main granodiorite mass, Piccaninny Point.
3B Poles to 160 biotite flakes, band two (see page 40) Piccaninny Point.
3C Poles to 250 biotite flakes, band one (see page 40) Piccaninny Point.
3D Poles to 160 biotite flakes, band one (see page 40) Piccaninny Point. Diagrams 3C, and 3D represent serial sections taken from the same specimen.
3E Optic axes of 250 quartz grains, band one (see page 40) Piccaninny Point.
3F Poles to 200 biotite flakes, band one (see page 40) Piccaninny Point.

plane of the projection is vertical, and two serial sections were used to obtain sufficient biotite flakes. There is a complete girdle of poles with four maxima. If the maxima are grouped together, to give two main maxima, the symmetry is almost orthorhombic. However, the maxima are slightly asymmetric and there is a tendency towards monoclinic symmetry.

The two compositional bands (see page 40) and the granodiorite sill gave similar results, (figures 3B, C. D. E and F).

The mineralogy of the granodiorite indicates that the magma was at least partly crystalline when intruded. The biotite flakes were easily oriented, but the quartz particles were shattered

and strained by the orienting forces. If it is assumed that the symmetry of fabric reflects the symmetry of deforming movements, it is apparent that the fabric is due to a combination of both monoclinic and orthorhombic movements. Further, the monoclinic movement appears to have been greatest at the contact, and least near the centre of the granodiorite. This could be explained by assuming that the monoclinic fabric at the contact is due to the drag of the magma against the wall or movement of the magma relative to the wall. This would decrease with distance from the contact. The tendency to form an orthorhombic fabric is due to confining pressure on the magma when intruded, the axis of maximum stress being near horizontal, and striking east-north east, and the axis of minimum stress vertical. This corresponds to the maximum and minimum stress directions at the time of the folding of the Mathinna Beds and probably indicates that the magma was intruded while folding was still active.

JURASSIC DOLERITE

Dolerite occupies almost a quarter of the area, and invariably caps the main hills, including St. Patrick's Head, Mt. Elephant, and the low plateau area south, and south-west of Gray. It is intrusive into the Triassic sediments where it appears to form slightly transgressive sheets. No intrusive contacts with Permian sediments have been mapped.

At St. Patrick's Head there are three possible forms of intrusion to be considered: the intrusion may be sill like, or slightly transgressive; it may be part of a sheet dipping to the west or north-west at 40 to 45 degrees; or it may be a neck of dolerite, cylindrical in plan with steeply dipping or vertical contacts on all sides.

The peak is elliptical in plan, elongated approximately east-west, and above the 1600 foot contour rises very steeply to the summit. This gives the impression in the field that there is dolerite in situ above this level, but definite outcrop does not occur until the 1800 foot contour is reached. All the dolerite is fine grained and can be classified within the lower zone of Spry (1958). If the intrusion was sill like, there must be a lower zone of fine grained dolerite at least 600 feet thick. This is much greater than the figure given by Spry (1958). If it is assumed that the dolerite was intruded as a sheet, dipping west at 30-45 degrees, the apparent thickness of the lower zone would be reduced considerably but would still be in excess of 400 feet. However, there is no evidence for this structure and the writer considers it an unlikely solution.

On the present evidence the last possibility appears to be the most favourable, i.e., the dolerite is in the form of a neck which is approximately 1 mile by half a mile.

South of St. Patrick's Head, Mt. Elephant is capped with 50 to 300 feet of dolerite, in the form of a slightly transgressive sheet.

The south-western and western parts of the Piccaninny Point square are covered by dolerite, but little is known of the form of intrusion. The eastern boundary of the dolerite with the Triassic System appears to be sill like or slightly transgressive in the northern half of the Piccaninny Point square and is repeatedly stepped down to the south by Tertiary faults. In the southern half of this square it may become more transgressive. The maximum thickness is difficult to estimate, but in the south-west corner it probably reaches 800 to 1000 feet. The thickness north-west of Dalmayne and south-west of Gray is rarely more than 200 to 300 feet.

Petrology

The dolerite at the southern end of Mt. Elephant and south of Gray can be classified within Spry's (1958) Lower Zone and consists of plagioclase 46%, pyroxene 45%, and mesostasis 9%. The texture is ophitic to intergranular, and the rock is clear and unaltered. The plagioclase is always labradorite and occurs as small laths averaging 0.3 to 0.4 mm. in length. Augite and pigeonite occur in approximately equal proportions and twinning is common in the pigeonites. The average size of the clino-pyroxene is approximately 0.8 mm. and rare orthopyroxene, possibly enstatite, occurs in well formed crystals up to 2 mm. long. A small amount of intersertal mesostasis is present, and consists of alkali feldspar, a little iron oxide and rare quartz needles.

Modal analyses of specimens from (A) the top of St. Patrick's Head (B) 350 feet, (C) 600 feet below the top, gave the following results:—

	(A)	(B)	(C)
Plagioclase	38.6%	39.9%	39.9%
Pyroxene	44.8%	40.9%	36.6%
Mesostasis	16.6%	19.1%	23.4%

The dolerite is always fine grained, both clino and orthopyroxene are present, and in B orthopyroxene is comparatively abundant. The mesostasis of some specimens appears to have been altered, and is quite dark and turbid, with abundant chlorite and iron oxide.

TERTIARY BASALT

A small exposure of basalt occurs on the north-western slopes of St. Patrick's Head at the 1600 foot contour. It is less than 10 feet thick, and is very limited in area. In thin section it has a microporphyritic texture with phenocroysts of pyroxene set in a groundmass of fine plagioclase laths and intersertal mesostasis. The plagioclase is labradorite and occurs as small lath shaped crystals averaging 0.15 mm. in diameter. The pyroxene (augite and pigeonite) averages 0.4 to 0.5 mm. in diameter and frequently has a sub-ophitic relationship to the plagioclase. The mesostasis is opaque and has abundant iron ore granules scattered throughout it.

STRUCTURAL GEOLOGY

TABBERABBERAN FOLDING

The only major folding of the area occurred in post-Silurian and pre-Permian times, and is considered to be due to the Devonian Tabberabberan

Orogeny. This folding involved only the Mathinna Beds, which were folded about axes that trend north-north-west.

Minor folds are well developed, but in only a few localities can they be studied in detail—notably the Elephant Pass region of the Mt. Elephant square. Several good sections at an angle to the strike occur in road cuttings and creek beds, and all observations on the folding of the area have been based on these outcrops. Forty measurements of minor fold axes have been plotted as figure 4. The figure shows two maxima, and the axis of the regional fold is assumed to be somewhere between them, i.e., about 335 to 340 degrees.

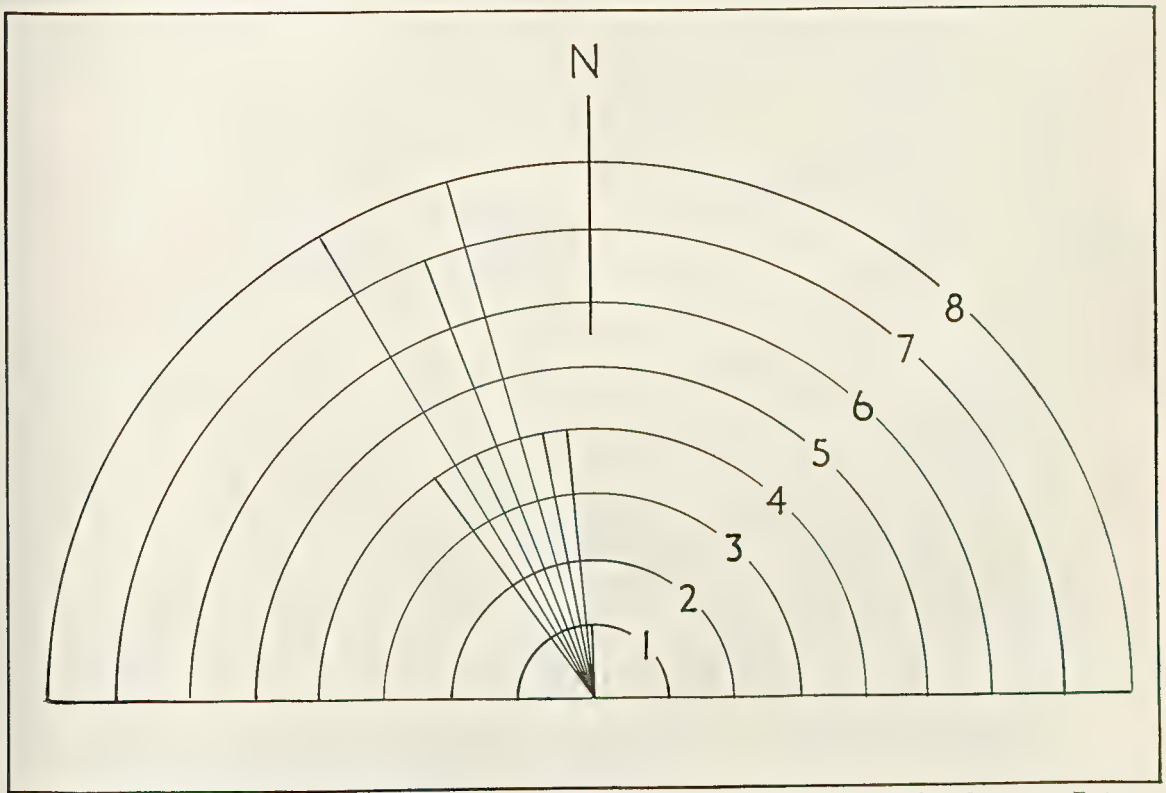


FIG. 4.—Rose diagram showing plunge directions of minor folds in the Mathinna Beds in the Elephant Pass area. Forty minor folds were measured and maxima are at 330 and 345 degrees.

The structure of the Mathinna Beds in the vicinity of the Elephant Pass was analysed by traversing road cuttings on the Tasman Highway, and the neighbouring creeks, including Wardlaw Creek, (figure 5). The fold axes in the Elephant Pass section vary between 340 and 350 degrees, whereas the axes exposed in the creeks, which are 400 feet lower, vary between 320 and 340 degrees. Thus, the minor fold axes swing slightly towards north as they ascend through the structure, (indicating a north pitching anticline or anticliorium to the east). In addition all minor folds plunge towards the north at angles varying between 3 and 30 degrees. Wavelengths vary from 10 to 100 feet.

Section B-B^1 (figure 5) indicates that the dominant dip is towards the west between B and C, a distance of 2700 feet, and that the axial planes of the minor folds dip steeply to the west. Between C and D, the area is more intensely folded, and the axial planes of the folds dip steeply to the east. Between D and E the sediments are still closely folded, but the axial planes of the folds dip east. Section A-A' (figure 5) is parallel to, but about 2000 feet south of, the main section. Although it is not possible to trace individual folds between these sections, the fold at B' of section B-B' is found at A' in section A-A' exactly where it would be predicted.

The whole section appears to correspond to one limb of a major anticlinorium centered east of point B.

A further section of Mathinna Beds is exposed on the coast just south of Piccaninny Point. Here the sediments are very closely folded, generally with axial planes which dip steeply to the west. All the minor folds plunge to the south at angles between 5 and 55 degrees, (average 15 degrees), and it is assumed that the major fold also plunges to the south.

The main structure in the Mathinna Beds appears to be a dome over the adamellite, the regional fold, (anticlinorium) plunging north in the Elephant Pass area and south at Piccininny Point. At this stage it is not possible to determine whether the adamellite occupied a previously formed dome or whether the intrusion actually caused the formation of the dome.

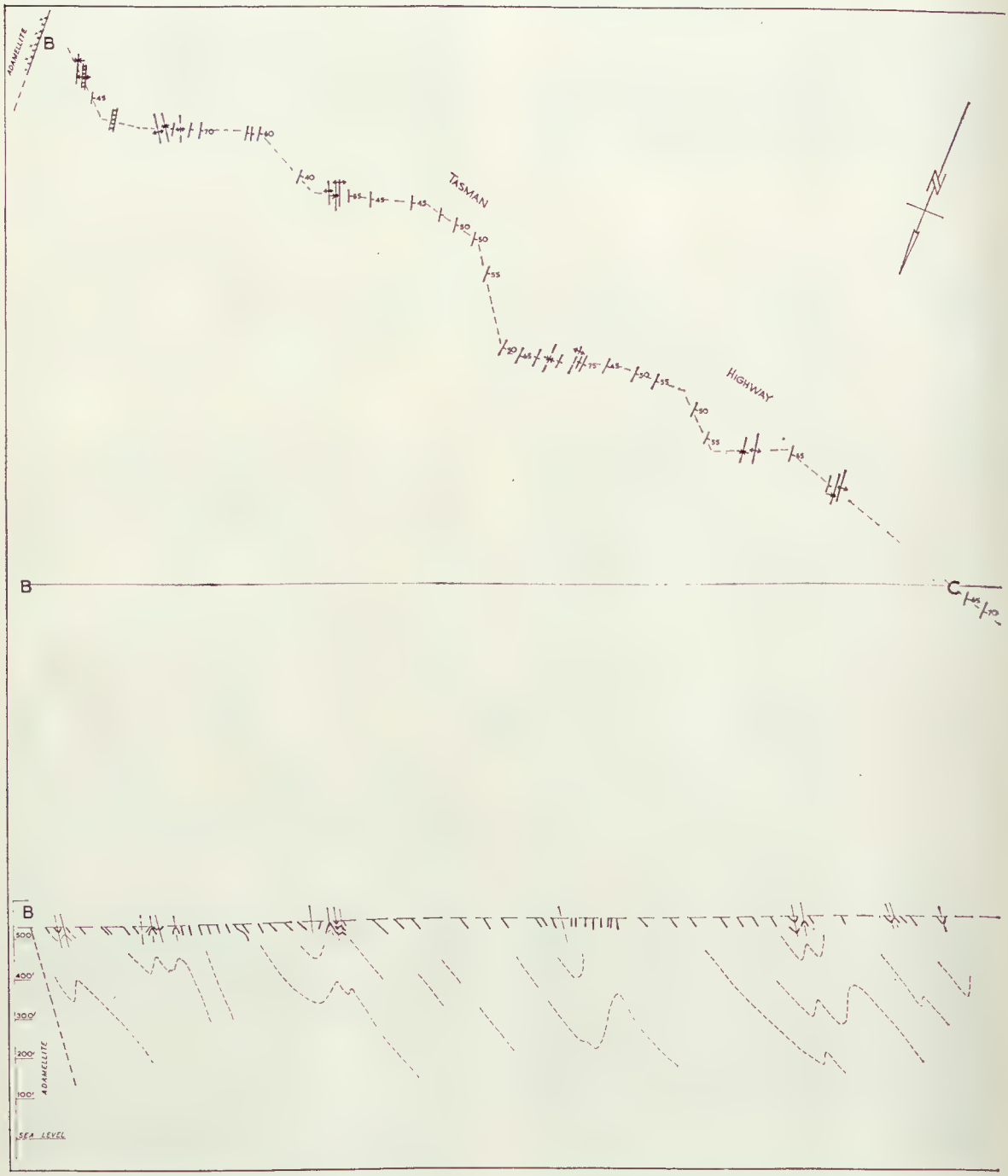
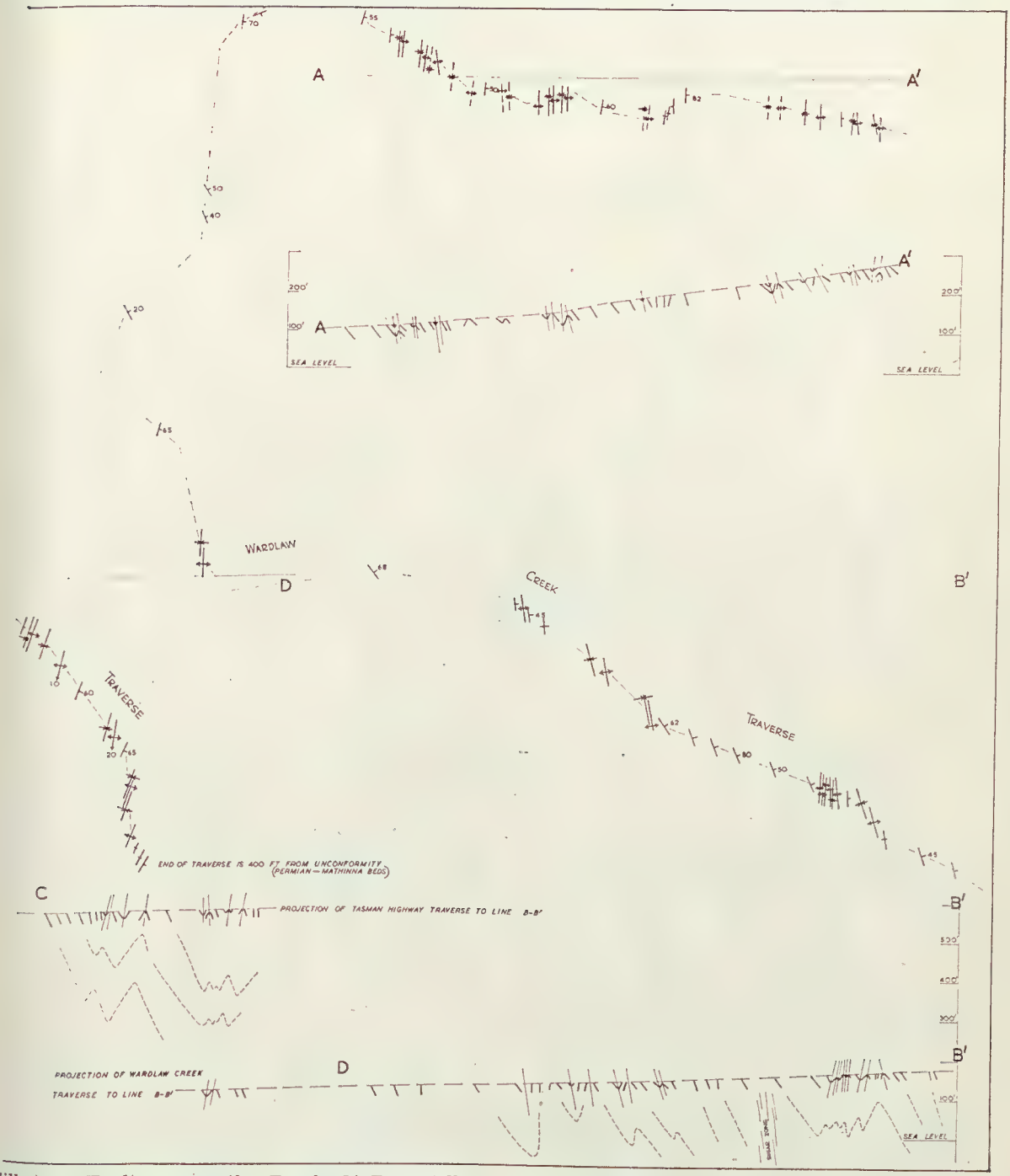


FIG. 5.—Plan and Cross Sections showing structure of Mathinna Beds in the Elephant Pass area.

TERTIARY FAULTING

Normal faulting, which is considered to be Early Tertiary in age (Hills and Carey 1949), has been of moderate magnitude, particularly in the south-western part of the Mt. Elephant square, and in the Piccaninny Point square. Keid's (Hills et al 1922) structural interpretation of the area has been revised, and although the Cornwall Fault exists in the south-west of, and to the west of the Mt. Elehpant square, it is not in the position shown by Keid. The down faulted trough shown on Keid's map in the Dalmayne area does not exist. Figure 6 is a diagrammatic map of the fault system.

The major structure of the region is a graben and horst, the Cornwall Graben occupying the upper part of the Break O' Day Valley between the Silkstone and Cornwall Faults, and the St. Marys Horst occupying most of the Mt. Elephant square between the Cornwall and associated faults, and north-west trending faults in the Falmouth square which have been inferred by Walker (1957). The



Silkstone Fault crosses the Break O' Day Valley in a north-westerly direction, just west of the Mt. Nicholas railway station, and is not shown on the accompanying maps. The position of the faults in the Falmouth square is uncertain, but they must exist as the Berriedale Limestone occurs at Enstone Park, and 1200 to 1500 feet higher on Ray's Hill near St. Marys.

Minor faults (throw of between 0 and 50 feet) are very common and were often encountered during the operation of the Dalmayne Colliery. Minor faults also caused several small mines around Mt. Elephant to be abandoned many years ago.

A marked linear occurs in the St. Marys

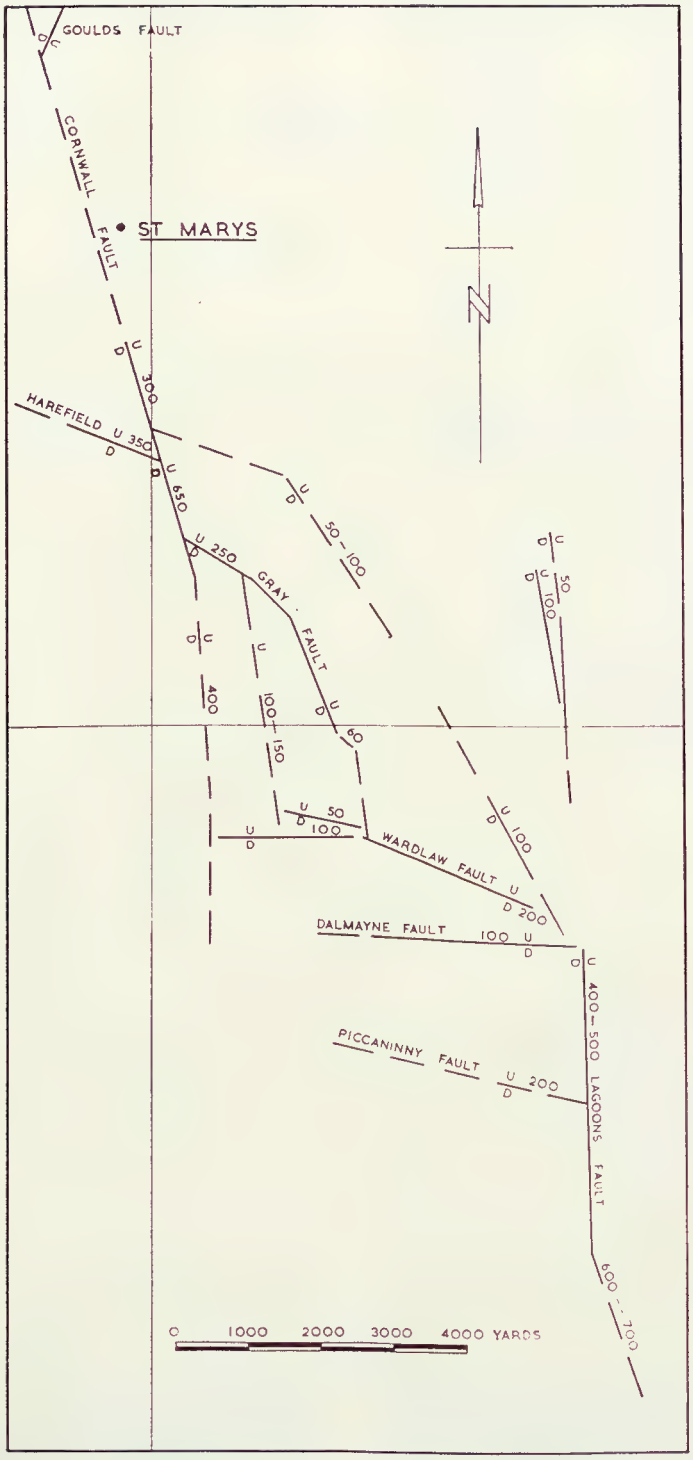


FIG. 6.—Diagrammatic map of Tertiary fault system in the St. Marys area.

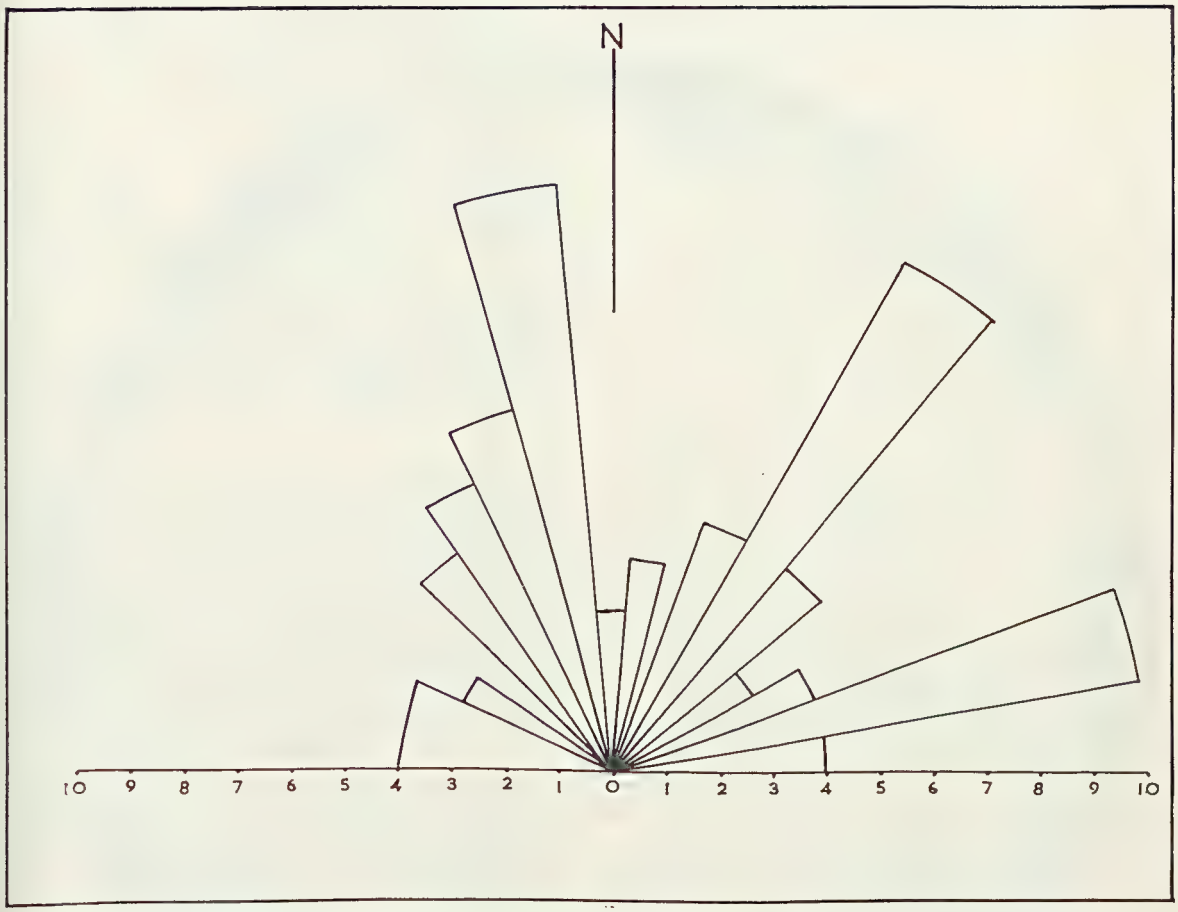


FIG. 7.—Rose diagram showing joint directions in the Permian and Triassic sediments in the Gray-Dalmayne area. Maxima are at 350, 35 and 75 degrees.

Porphyry to the north-east of Mt. Elephant. It strikes north-east and follows the valley of Four Mile Creek, but does not cut the overlying Permian beds, and is probably a pre-Permian fault.

JOINTS

Joints were measured in the Permian and Triassic sediments. The majority of joints are concntrated along the following trends: 350, 35 and 75 degrees (figure 7).

Joints in the St. Marys Porphyry were measured at widely scattered outcrops over the whole intrusion and the poles to the joints were plotted on a stereogram (figure 8). Major maxima (8%), occur at 350 and 40 degrees, corresponding to two sets of vertical joints striking at 80 and 310 degrees respectively. Minor maxima (6%) occur at 85 and 310 degrees, corresponding to two sets of vertical joints striking 355 and 40 degrees respectively.

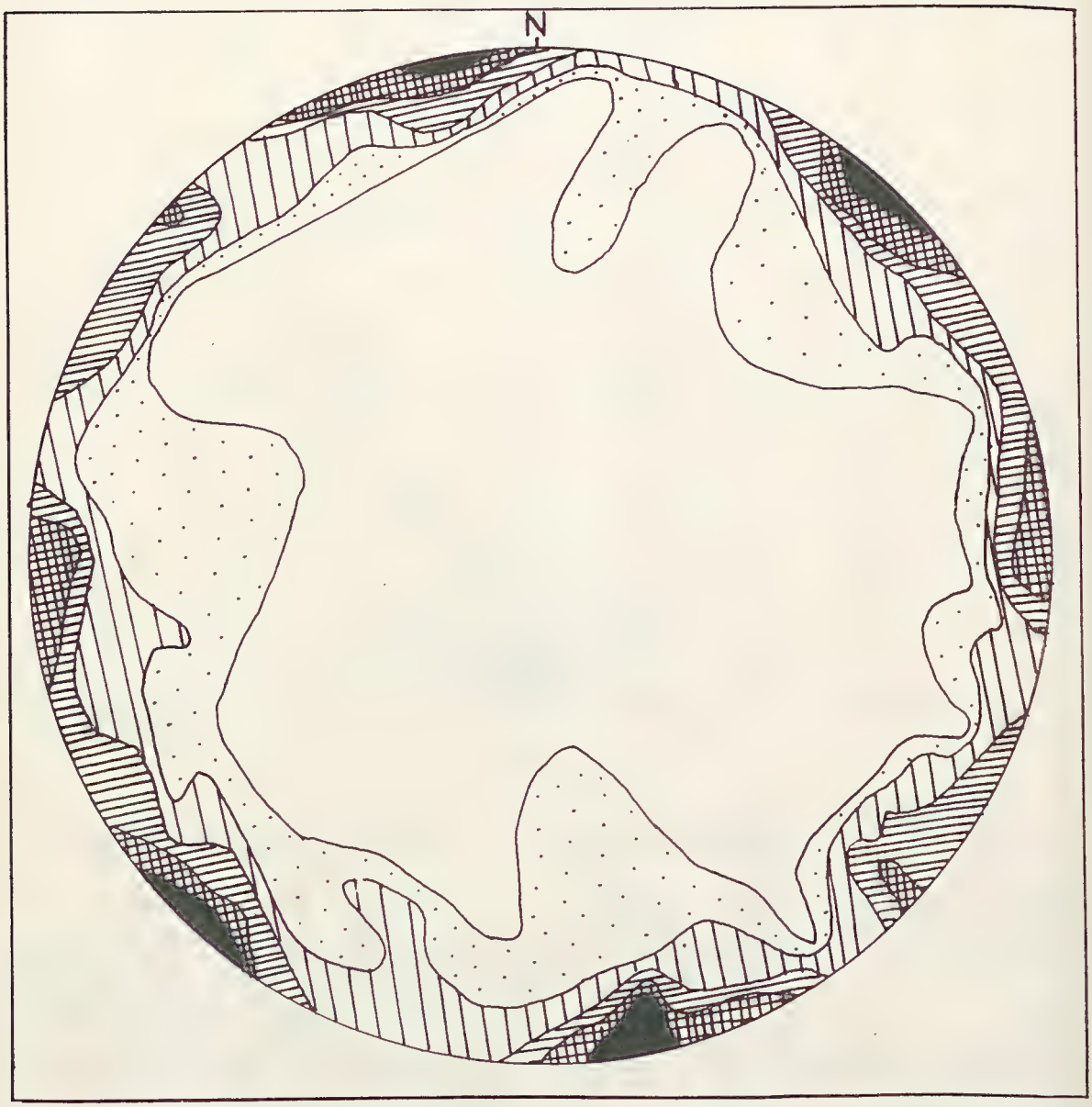
The 350, 35 and 75 degree trends in the sediments are probably equivalent to the 355, 40 and 80 degree trends in the St. Marys Porphyry.

SUMMARY AND CONCLUSIONS

The oldest rocks exposed are Upper Silurian and, or, Lower Devonian in age, and consist of monotonous, well bedded greywacke sandstones, greywacke siltstones, and mudstones. The sediments are mainly turbidity current deposits, the currents originating to the south-west and west.

The Middle Devonian Tabberabberan Orogeny caused shallow folding of the Mathinna Beds, with very little accompanying metamorphism. The main fold structure postulated is an anticlinorium, which trends N.N.W. east of the Elephant Pass.

At or near the end of the folding, the St. Marys Porphyry was intruded in the form of a thick sheet or lens shaped intrusion, approximately 4000 feet thick. The porphyry was partly crystalline and at a relatively high temperature (sanidine and anorthoclase are present) when intruded. The St. Marys Porphyry was followed by an intrusion of adamellite which metamorphosed the porphyry along its southern boundary. The adamellite was intruded along the axis of an anticlinorium



POLES TO 185 JOINT PLANES IN THE ST MARYS PORPHYRY.

EQUAL AREA PROJECTION. CONTOUR INTERVAL 8,6,4,2 & 1%.

(Carey's Ringarooma Anticlinorium). The intrusion may have domed up the Mathinna Beds slightly. Contact metamorphism is generally slight, but at Piccaninny Point the granitic fluids and gases were concentrated and high temperature thermal metamorphic rocks which contain sillimanite, corundum, cordierite, microline and andalusite were developed.

Peneplanation, which followed the Tabberabberan Orogeny, appears to have been fairly complete, except to the east, where the resistant St. Marys Porphyry formed low hills at the beginning of Permian sedimentation.

Permian sedimentation (with marked unconformity to the Mathinna Beds), probably began in the Lower Artinskian, and continued through to the Kungurian or later. The sediments are dominantly marine, and consist of sandstones, greywacke sandstones, greywacke siltstones, limestones and mudstones.

Above the Permian System were deposited at least 700 feet of sandstone, granule conglomerate, and subgreywacke sandstone of Triassic age. Disconformity is indicated by the presence of basal sandstones and granule conglomerates, which thicken and thin rapidly and are probably infillings of former valleys; and by the variable thickness of the Ferntree Mudstone which was probably partly eroded before the deposition of the Triassic sequence. The Triassic sediments were deposited in a series of large shallow lakes. The climate was probably hot and humid and there was sufficient vegetation to allow the formation of allochthonous coal seams up to 16 feet thick.

Triassic sedimentation was probably terminated by the intrusion of dolerite during the Jurassic. Peneplanation after the intrusion of dolerite and tensional faulting in the early Tertiary, followed by normal weathering and erosion has produced the present day topography.

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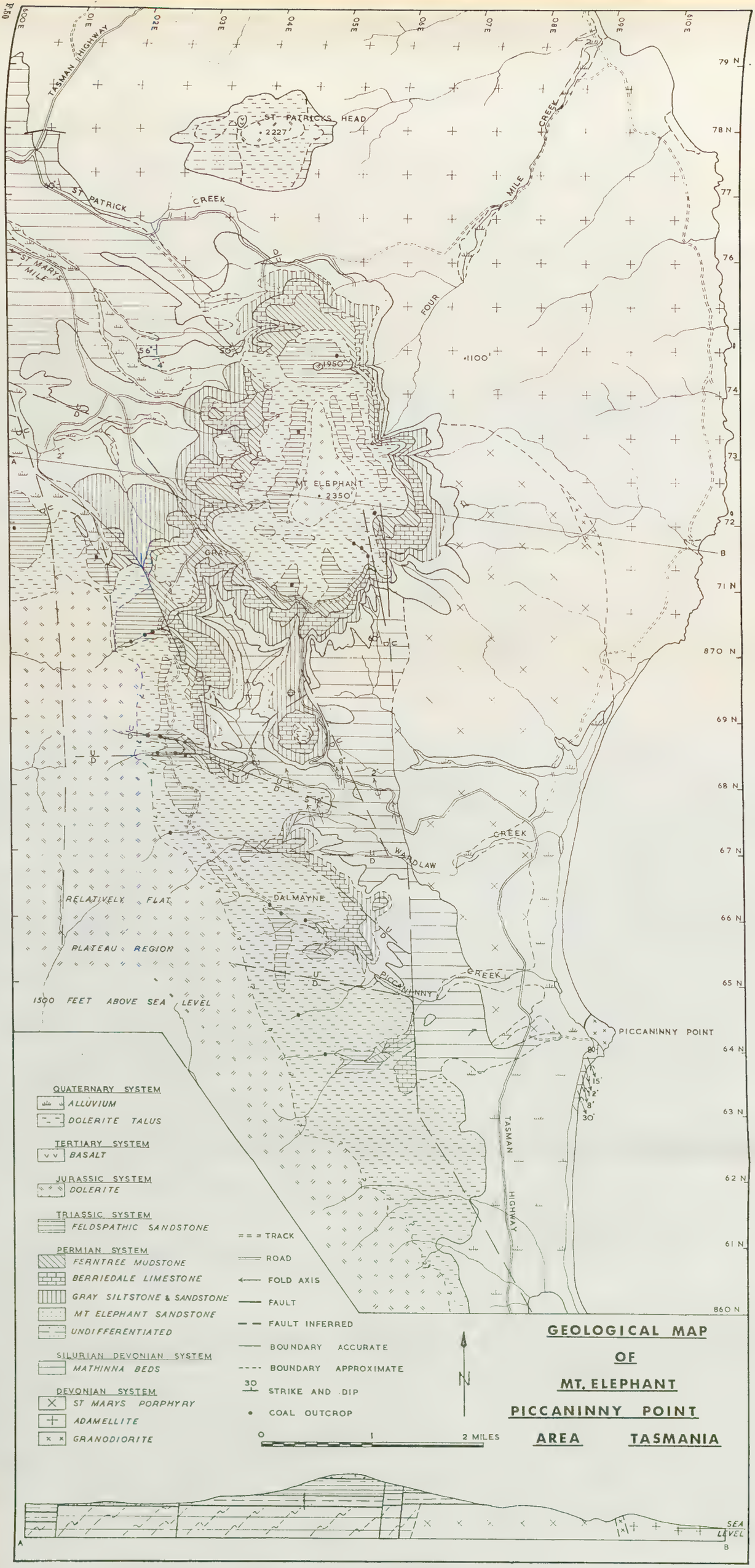

GEOLOGICAL MAP OF MT. ELEPHANT PICCANINNY POINT AREA TASMANIA

THE OCCURRENCE OF RHENIUM IN SOME TASMANIAN MOLYBDENITES

By

R. J. Ford

Geology Department, University of Tasmania

The element rhenium is known to form only one extremely rare mineral dzhezkazganite. Much of the rhenium in nature occurs in small quantities, usually in the parts per million range, substituting for molybdenum which is a chemically similar element. An investigation was carried out to determine the amount of rhenium in some molybdenites of Tasmanian origin. Samples were supplied by the Tasmanian Mines Department, Tasmanian Museum and the Queen Victoria Museum. Analyses were originally attempted using a colorimetric technique, however this appeared unreliable with the equipment in use and most of the samples were eventually analysed through the co-operation of Dr. J. F. Lovering and Mr. J. W. Morgan of the Australian National University using neutron activation as the analytical technique.

The following results were obtained (values are given in parts per million) :—

Blue Tier—0.76.
St. Helens—2.00
Mt Stronach—2.00 (R.J.F.)
Flinders Island—0.47

Moina—

Shephard and Murphy Mine—0.93
Premier Mine, Dalcoath—0.35

Middlesex Plains—1.6
Mt Heemskirk—0.0091
Mt Lyell—7.17
Mt Bischoff—8.00
King Island—40.00

Thus from the specimens analysed it may be concluded that in spite of the relatively high concentration of rhenium in the King Island sample, Tasmania is a rhenium poor geochemical province.

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OBSERVATIONS OF SOME TASMANIAN FISHES: PART XIII

By

E. O. G. Scott

(With one text figure.)

ABSTRACT

Gymnothorax leecote sp. nov. [Muraenidae], the first member of the family recorded from Tasmanian waters, is described and figured. Other additions to the State list are *Petraïtes heptaeolus* Ogilby, 1865 Clinidae], *Ophiclinus gabrieli* Waite, 1906 [Ophiclinidae], *Callogobius hasseltii* (Bleeker), 1851 [*Gobiidae*], *Tetraodon firmamentum* Temminck & Schlegel, 1850 [Tetraodontidae].

Miscellaneous observations are made on *Muraenichthys tasmaniensis* McCulloch, 1911 [Echelidae] (description of a specimen from Green's Beach, Devon); *Urocampus carinirostris* Castelnau, 1872 [Syngnathidae] (meristic and other metrical data; relative growth of body segments); *Clinus perspicillatus* Cuvier & Valenciennes, 1836 [Clinidae] (general observations; proportions in sample from Taroona, Buckingham); *Ophiclinus greeni* Scott, 1936 [Ophiclinidae] (new material; status of species).

Specifications of standard length of populations of some of the above-mentioned species as sampled in the course of routine collection are noted and commented on. Some data on catches made at a Fishing Competition at George Town, Dorset in December 1963 are reported.

Keys are provided covering the Tasmanian members of the Echelidae, Ophiclinidae.

INTRODUCTION

This paper follows the general plan of others in the series. The symbols *Ls*, *Lt* denote standard length, total length, respectively; *TLs*, *TLt* signify thousands of standard, of total, length. All linear dimensions are in millimeters, the name of the unit commonly being omitted.

Family Echelidae

All the 3 Tasmanian members of the family—*Muraenichthys breviceps* Günther, 1867, *M. australis* Macleay, 1881, *M. tasmaniensis* McCulloch, 1911—have at various times been the subject of comment in these Observations (1936, 1953, 1957, 1961, 1963). However, in well over a quarter of a century only one specimen of *M. tasmaniensis* has come under notice: the receipt of a second individual is the immediate occasion of the notes below.

As pointed out in 1961, the transposition of 2 clauses renders a key provided in 1957 self-contradictory. A redrafted key is here offered. (Schmidt's index, $S = \frac{a-d}{t}$, where a = length to vent, d = length to origin of dorsal, t = total length).

Key to Echelidae Recorded from Tasmania

1 { Dorsal originating in advance of vent; *i.e.*, *S* positive [16-23]. Teeth in the jaws biserial .... *M. breviceps*
1 { Dorsal originating behind vent; *i.e.*, *S* negative [(—6)-(—8)]. Teeth in the jaws uniserial 2

2 { Interval between anal and dorsal origins >3 ($=$ 5-7) in head. S = (—1)-(—3) .... *M. australis*
2 { Interval between anal and dorsal origins <3 ($=$ 1-2) in head. S = (—6)-(—8) .... *M. tasmaniensis*

Genus **MURAENICHTHYS** Bleeker, 1865

MURAENICHTHYS TASMANIENSIS McCulloch, 1911

Muraenichthys tasmaniensis McCulloch, 1911, Zool. Res. *Endeavour*, 1: 19, fig. 5. Type locality: Oyster Bay [Pembroke], Tasmania.

Record.—A specimen found alive under wet sand above low-water mark at Green's Beach, Devon on 28th December 1963 by Mr Henry King (Queen Victoria Museum Reg. No. 1964:5:3) is much longer (*Lt* 265) than the holotype (170) and the Deviot specimen noted in the 1961 contribution: however, Munro, whose distribution includes Western Australia, gives 11 inches as overall length for this species.

Proportions.—For the ratios recorded in the description of the holotype (the values for which are noted in parentheses) we here find: depth 2.9 (3.3) in head; head 13.3 (12.3) in *Lt*, and 4.8 (4.3) in space between gill opening and vent; eye 4.0 (3.2) in snout; snout 5.7 (4.8) in head; cleft of mouth 4.1 (2.7) in head; preanal length 1.3 (1.4) in postanal length; dorsal origin 4 mm nearer to tail-tip than to snout-tip ('a trifle nearer the tip of the snout than the tail'); distance from dorsal origin to vent 0.93 head ('equal to the length of the head').

Some proportions, as *TLt*, for comparison with those of the Deviot fish (values in parentheses) may be noted. Length to: vent 438 (414), anal origin 460 (424), dorsal origin 508 (480). Length of: eye 3.4 (4.0), snout 13 (15), head 75 (81), mouth-cleft 25 (27). Depth at: back of eye 15 (10), middle of branchial sac 17 (23), gill opening 20 (21), vent 24 (20). Width at the same four points 11, 15, 19, 21 (10, 13, 15, 20). S = —6.79 (—6.60).

The maximum depth, occurring at about 75-80 behind snout-tip, is 26 *TLt*, the width there being 22 *TLt*. Interorbital 2.0 eye.

Coloration.—The living fish was noted as being pale yellow, lighter below; head with a pink flush. In the preserved specimen the trunk above the lateral line is yellowish, fainty greenish, with closely spaced dark chromatophores; except for

about the first 20 of the ventral surface, which is reddish golden, all below the lateral line is immaculate, yellowish. Just behind the vent the chromatophores begin to extend below the lateral line, and continue increasingly to do so caudad, virtually reaching midventral line at tail-tip; at the same time they become smaller, deeper in color, more sharply defined. A narrow band of very closely set chromatophores, much smaller than those on upper side of trunk, embraces the sunken dorsal. Dorsum of head anteriorly ivory, with small brownish chromatophores, most numerous in advance of hind margin of eye; posteriorly like upper part of lateral surface of trunk, but with warm brownish flush. Side of snout above mouth cleft somewhat greenish with abundant minute brownish vermiculation; side of lower jaw dark, anteriorly almost black; backward from snout side of head successively deep ivory, yellowish, slatey (branchial sac). Under surface of head pale brownish to just behind level of end of oral groove, thereafter yellowish immaculate.

Preanal and postanal length in three species.—An inspection of the measurements of the specimens of three Tasmanian species of *Muraenichthys* recorded in these Observations suggests the preanal-postanal length ratio may be diagnostic; however, data are available for 1 specimen only of *M. australis* and for 2 only of *M. tasmaniensis;* though the mean for 9 examples of *M. breviceps* is highly significant ($t = 119.7^{**}$). Expressed as *TLt* the preanal length is: *M. australis* (1936) 336, *M. breviceps* (1953, 1957, 1963) 357-384, mean 374.2 $\pm$ 4.00, *M. tasmaniensis* (1961, present paper) 438-414, mean 426.0 $\pm$ 8.49. The standard deviation (using n-1; elsewhere in these calculations n is used) for *M. breviceps* is 12.73: thus the value for *M. australis* differs from the mean for *M. breviceps* by 3.0σ, and from that for the lower value for *M. tasmaniensis* by 3.1σ, indicating the three series of *TLt* are indeed probably distinct.

In *M. breviceps* relative precaudal length is positively correlated with total length: for the 9 specimens $r = + 0.791$, $z = 1.074$, $t = 3.42^{*}$. As an indication of the order of magnitude of the quantities involved it may be noted that for the greatest *Lt* (283, shared by 2 specimens) length to vent, expressed as *TLt*, is 377, 384, mean 380.5, while for the least *Lt* (234.8) it is 364 (N.B., larger than the value, 357, for the next smallest individual, of *Lt* 313.5); the corresponding predicted values calculated from the second regression given below are 379, 348—*i.e.*, over the relevant *Lt* range the value of length to vent, as *TLt*, varies about 1%. For the 6 individuals of 1957 the regression equation of length to vent (*Lv*) on *Lt* is found to be

$$Lv = 0.3982\ Lt - 10.06,$$

with $t = 57.29^{**}$ (1957: Table II). For the 9 fish it is

$$Lv = 0.4004\ Lt - 12.33,$$

with $t = 12.93^{**}$. A comparison of values of *Lv* predicted by this last equation with actual values shows divergences of 0.4-7.9, mean 2.2, mm; or 0.2-4.5, mean 1.6, %.

Family Muraenidae

Of the 27 members of the family accepted as Australian in Munro (1957), 14 are referred to *Gymnothorax* Bloch, 1795—other genera being *Arndha* (1 species), *Siderea* (2), *Echidna* (2), *Fimbrinares* (1), *Uropterygius* (4), *Notorabula* (1), *Thyrsoidea* (1), *Muraena* (1). *Gymnothorax* is characteristically a warm-water genus, all our described species save 1 (?2) occurring in Queensland; 4 being reported from Western Australia (1 restricted to the tropics); with on the east coast 3 only extending as far south as New South Wales, one of these, *G. prasinus* (Richardson), 1848, reaching Victoria: there are no records for South Australia or Tasmania.

The family now first appears in the Tasmanian list, a moray eel from the East coast referable to *Gymnothorax,* but not agreeing with any known Australian species, being described below.

Genus **GYMNOTHORAX** Bloch, 1795

GYMNOTHORAX LEECOTE sp. nov.

(Fig. 1)

Diagnosis.—Length of head and trunk together slightly exceeding length of tail. Head about 9-10, maximum depth about 15, in total length. Fins low. Anal origin behind vent by about combined eye and snout. Dorsal originating in advance of gill slit by less than length of that opening, which is level horizontally with eye. Snout convex; head rising sharply behind middle of eye. Anterior nostril a simple tube, when depressed not reaching lip-border. Posterior nostril in front of, shortly below level of top of, eye; an oblique slit, with free cutaneous fringe. Mouth not closable; upper jaw projecting; cleft about half postorbital head. Maxillary and dentary teeth biserial; intermaxillary teeth include 3 median, of which first and last are partly depressible fangs: vomer edentulous. Brown, with darker mottling and vermiculation on head and anterior part of trunk; all markings small, closely set, modal diameter of the rounded ones about one-sixth that of eye: fins concolorous with body. Total length (holotype) 815 mm.

Description.—Principal dimensions expressed as *TLt,* (actual measurements, mm in parentheses) are as follows: Length to: origin, termination of dorsal (76.5, 812) 94, 996; origin, termination of anal (430, 809) 528, 993; gill slit (85) 104; middle of vent (410) 515. Depth at: front of eye (25) 31; back of eye (30), 37; gill slit (55) 67; midway between gill slit and vent (46) 56; vent (42) 52; midway between vent and tail-up 40. Thickness at the same points: (14.5) 18; (16) 20; (21) 26; (23.5) 29; (21) 26; (16) 20—but the plastic and 'lumpy' nature of the trunk and tail make measurements of thickness, other than those of the head, somewhat unreliable.

Some dimensions in head (85 mm.): snout (15.5) 5.4; eye (5.5) 15.5; interorbital (9.6) 8.9; mouth cleft (34) 2.5; gill slit (9.1) 9.3; internarial, anterior nostrils (7.5) 11.3; internarial, posterior nostrils (7.9) 10.8; rictus to eye (20) 42.5.

Dorsal profile almost evenly convex to level of middle of eye, thereafter rising in a single sweep to shortly before level of gill slit; descending in a slow convex segment for about 1½ head-lengths; continuing more or less straight throughout most of its length; finally curving down, through about

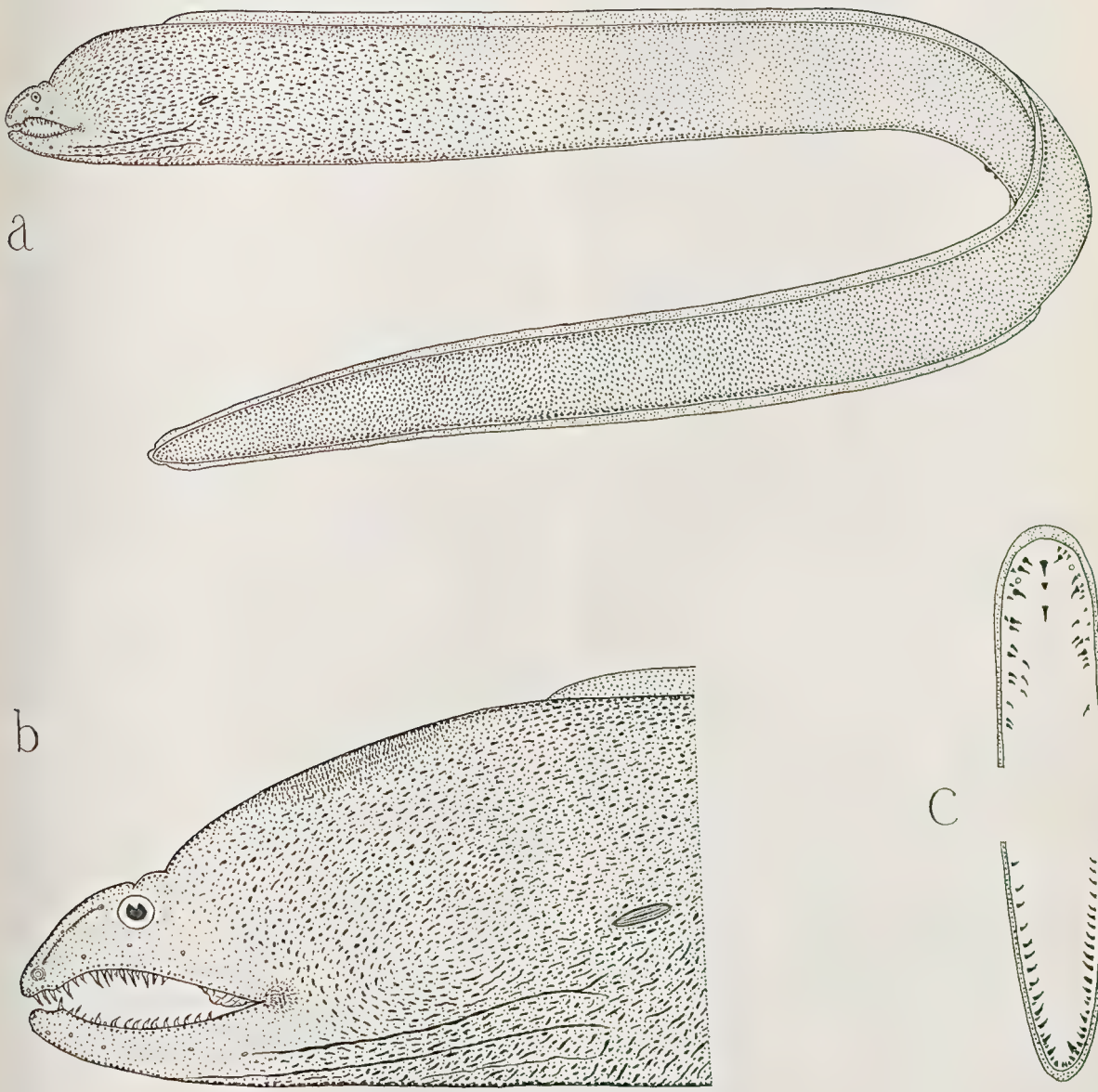

Fig. 1.—*Gymnothorax leecote, sp. nov.* Holotype, total length 815 mm, from off George Rock near St Helens, Cornwall, Tasmania (in Crayfish net set at 10 fathoms; Mr John Lipsius). *a.*—Lateral aspect; x about 7/20. *b.*—Head; about nat. size. *c.*—Dentition; about nat. size.

1 head-length, to the rounded tail-tip. Ventral profile almost linear throughout, curved up at lower jaw.

The origin of the dorsal fin is not readily located, a superficial examination suggesting the fin (which anteriorly is very low) runs forward to the point of inflexion in dorsal profile at level of middle of eye: however, a slight dissection fails to disclose the presence of fin rays anterior to a point situated 1/10 head-length in advance of level of gill slit. Owing to its fleshy nature the fin is not sharply delimited basally from the body, making precise measurement of its altitude, which is nowhere great, a matter of difficulty: approximate heights at hind end of gill slit, midway between gill slit and vent, at vent, midway between vent and tail-tip are 3, 6, 6, 5 respectively, or 5, 13, 14, 15 % of depth of body at these points. Fin ceases within 1 mm of level of end of fleshy tail, a decrease in height here marking its confluence with the caudal. Anal low, fleshy; its origin, near which it is barely elevated above fleshy part of tail, behind vent by a distance equal to that from tip of snout to middle of eye, or rather more than twice length of gill slit. Throughout most of its extent its height is less than (at its middle about half of) that of dorsal opposite it, but in its last ½ head-length, or so, its height more closely approximates that of the other fin: at about ⅔ of an eye-diameter in advance of (fleshy) tail-tip, at which point its height exceeds ½ an eye-diameter, it lapses to confluence with the much lower caudal. Caudal has superior, inferior lengths of 3, 6; extends behind fleshy tail-tip by about 2.

Eye rather small, 2.8 in snout; middle about over middle of gape; about twice as far from upper lip as from dorsal profile; 1.8 in interorbital. Mouth does not close; upper jaw (tip of which exceeds tip of mandible by 1.5, or 0.4 eye-diameter) with upwardly convex, lower jaw with upwardly concave, profile. With jaw-tips opposed, vertical distance between bases of upper and lower teeth, at maximum near middle of mouth-cleft, is 8, or a trifle more than ½ snout-length; the lacuna between tips of teeth is about half this. Contact of the jaws anteriorly is brief, free space occurring between them through an anteroposterior interval of 25, or ½ distance between rictus and gill slit.

The dentition (fig. 1*c*) presents some irregularities: differences between the two sides are clearly due in part to injury, but appear to be in some degree intrinsic. Intermaxillary with (*a*) an outer row of about 5-7 on each side, small to minute, mostly rather blunt but one or two on each side tolerably sharp: (*b*) a row, just inside (*a*), of about 9-11 on each side, the first 4 (right side) closely set, smallish, subequal, bluntly subulate, the remainder spaced, the first 2 (left side) of moderate size, the tips shouldered or with incipient lateral cusps, the others more nearly conical, more sharply pointed, the whole series increasing in length backwards to the last (right) or antepenultimate (left) tooth: (*c*) immediately inside the 3 more anterior of the 4 closely set group of (*b*), a single tooth, about twice the size of those in front of it, base bulbous, tip rather compressed with shoulders or rudimentary horizontal cusps (tooth present only on right; some indications of possible former presence of a fellow on left): (*d*) 3 median teeth, 1st, shortly behind level of 2nd spaced tooth of (*b*), a large conical, recurved, partly depressible fang; 2nd, about at level of 3rd spaced tooth of (*b*), and inserted about its own length behind base of 1st median tooth, small, triangular, anteroposteriorly compressed, wholly depressible; 3rd, about at level of 4th spaced tooth of (*b*), largest tooth in mouth, similar to, a trifle slenderer, but longer, than 1st median. Each maxillary with (*a*) an outer row of about 8, the first few of moderate size, stoutish, rather blunt, the remainder increasingly smaller, more recurved, slenderer, sharper: (*b*) an inner row of 3 (? more), starting at, or just behind, beginning of outer row, finer and a shade longer than teeth of that series. No teeth on vomer. Each dentary with (*a*) an outer row of 9-11, extending back somewhat beyond middle of jaw, two or three among the anterior ones small, stout, subulate, blunt, those behind decreasing more or less regularly to minute, and becoming progressively more conical, relatively more slender, sharper: (*b*) an inner row of about 20, the 1st and 2nd subequal, of moderate size, the 3rd, 4th, 5th large, subequal (on right, 4th is slightly larger than 3rd, 5th the largest in the jaw; on left, where only 4th and 5th remain, the former exceeds the latter, being as large as 5th of right); others decreasing tolerably evenly in size backwards, those in the right jaw tending to become sharper and more recurved posteriorly, those in the left being sharpest and most recurved near the middle of the series. Several teeth on the intermaxillary show a small number of minute serrations on the posterior border and in 2 of the 4 closely set teeth of series (*b*), on right, these are present on both posterior and anterior surfaces: similar serrations or asperities occur on the posterior surface of several maxillary teeth of series (*a*) and of a few dentary teeth of series (*b*).

Broadly, the pattern appears to resolve itself to this. Intermaxillary: 3 peripheral and 1 median row (peripheral: outer, 5-7 teeth, anterior ⅔ of bone; middle, 9-11, whole length; inner, 1, near tip of jaw—all on each side. Median: 3, of which 1st and 3rd are fangs). Maxillary: biserial (outer row, about 8, whole length; inner, 3 (or more?), opposite front half of outer—on each side). Dentary: biserial (outer row, 9-11, front half of jaw; inner, about 20, whole length—on each side). Vomer edentulous.

Anterior nostril lies in a subcircular depression, the diameter of which (3) is about twice its distance from lip-border; from a low subspherical basal sac, 1.7 in diameter, nostril extends upwards as simple tube (left, subconical; right, somewhat compressed obliquely forwards and outwards) terminating in a simple transverse slit, set obliquely, its inner termination in advance of its outer; when depressed forwards tube does not reach beyond border of narial basin; distance (dividers) of middle of slit from tip of upper jaw about 3½ in its distance from eye; internarial (middles of slits) 7.5, about 3 in combined eye and snout. Posterior nostril an oblique slit, sloping forwards and downwards; its length 1.5, a trifle less than basal diameter of anterior nostril; edge in the form of thin, flattened continuous fringe of integument that can

be withdrawn from the cavity and folded back over the adjoining snout-skin, the outer reflected margins along sides of slit then being about 2 apart; about ⅛ eye-diameter in front of eye, on horizontal level with upper ⅓ of eye; least distance from eye 2.8, half shortest distance from eye to border of upper lip; internarial (middles of slits) 7.5, rather less than shortest distance from nostril to border of upper lip.

Six pairs of pores observed on head above mouth, disposed on each side thus: (*a*) below, just internad of, anterior nostril, about equidistant from nostril base and lip-border; (*b*) above anterior ¼-⅓ of anterior nostril on rim of a dark annulus more or less coinciding with narial depression; distant from nostril by rather less than ½ basal diameter of latter; (*c*) on superolateral surface of snout, lying on an arc, subparallel with dorsal profile, from anterior to posterior nostril; a shade closer to (*b*) than to posterior nostril; (*d*), (*e*), (*f*) in a line above, parallel to, upper lip; intervals between (*d*) and (*e*) and (*e*) and (*f*) equal, also equal to distance of (*e*) from anterior nostril and to its distance from eye; (*e*) below first ¼-⅓ of eye; direct distance of (*f*) from hard angle of mouth slightly exceeds its disance from (*d*). Six pairs were found also on lower jaw, the first (*g*) almost at tip of jaw, about below (*a*), the last (*l*) vertically below, or a trifle in advance of the level of, angle of mouth; the intervals between pores increasing backwards; the hinder five (*h*)-(*l*) approximately in a linear series, their distance from lip-border increasing backwards, that of (*h*) being ⅔, that of (*l*) 1½, eye-diameter: on account of the upturn of the jaw-tip (*g*) lies somewhat above the horizontal level of the rest.

Gill opening a simple longitudinal slit, or elongate ellipse, directed forward and slightly downward; about on horizontal level with bottom of eye, from anterior border of which it is distant two mouth-lengths; nearer to ventral than to dorsal profile; its length a little less than interorbital width.

An aperture (urinary pore?) lies just behind vent; interval between middles of the openings (each of which perforates a low protuberance) 5, subsequal to diameter of vent.

Head with warm brown ground color, almost uniform, but a trifle lighter on under side of lower jaw, and, on left side, on cheek; an elongated median darkish patch on middle one-third of dorsum; except on sides and on anterior one-third of ventral surface of lower jaw, abundantly dappled and vermiculated with darker brownish, the markings small and rather faint on the cheeks, elsewhere larger, clearer, and somewhat darker; on the lower surface, beginning about at level of eye, there run back one narrow median blackish stripe, best developed anteriorly but traceable as a slender line to level of gill opening, and two pairs of blackish lines diverging posteriorly, the outer the more conspicuous, traceable on right side close to, on left side to, level of gill opening, its termination being about equidistant from the opening and the termination of the median stripe; at rictus a small blackish patch, somewhat different in form on the two sides; a darkish stripe joining anterior nostril with posterior, the former lying in a small dark narial basin, the skinny fringe surrounding the opening of the latter black; some interorbital duskiness. Gill opening narrowly margined with blackish; internally, whitish above, greyish minutely and abundantly punctuated with brownish below.

The anterior one-fourth of the trunk does not differ greatly from the head, save for a progressive deepening posteriorly of the ground color. Behind this the dappling, the dark elements of which now become rounder and more clearly separate than on side of head, begins to become indistinct above the midlateral line and to be restricted, in an increasing degree, to lower part of lateral, and to ventral, surface: the dark spots, which are closely set, do not exceed 1 mm in diameter. In the last one-fourth of the trunk no markings are apparent, and, except narrowly along the midventral line where it remains deep warm brown, the ground color, as the result of a progressive deepening, becomes very dark brown, approaching black.

The dark to very dark brown tail lacks markings. The ground color is lightest on the sides of the anterior one-fourth, flanking the bases of the fins for much of the length, and generally in the distal 35 or so.

The dorsal, anal and caudal fins, which are feebly developed, are in general concolorous with the body near them; but on the trunk the dorsal fin is narrowly margined intermittently (in all for about two-thirds of its preanal length) with blackish.

Material.—Described and figured (fig. 1) from the unique holotype, *Lt* 815 (Queen Victoria Museum Reg. No. 1964:5:15). The specimen was obtained by Mr John Lipsius of St Helens and brought to the Museum for identification by Dr H. S. Blackburn.

Locality.—Captured in July 1963 in a crayfish pot set in 10 fathoms off George Rock, north of St Helens, Cornwall, Tasmania: the latitude of St Helens is 41° 20′ S. It may be remarked that the Eastern Australian Current extends southward along the east coast of Tasmania, its distance offshore being subject to seasonal variation. Of the few sea snakes recorded from Tasmania most were obtained in this region (*e.g., Laticauda laticaudata* Linné), 1758, Scamander (Lord, 1920), St Helens (Scott, 1932); *Hydrophis ornatus ocellatus* Gray, 1849, captured at St Helens (Scott, 1932), though generally regarded as a northern Australian species and not previously reported (Kinghorn, 1929: 112) south of the Hawksbury River, New South Wales, where an example was caught in 1925). These were clearly stray individuals, and it is possible our moray may be a current-following visitor from warmer waters.

Name.—The fish is reported to have fought viciously when brought to the surface, a circumstance commemorated in the trivial name *leecote,* a Tasmanian aboriginal word signifying *rage* in the dialect of the 'tribe about Mount Royal, Brune [now usually Bruni, or Bruny] Island, Recherche Bay, and the South of Tasmania' (see Joseph Milligan's vocabulary in Ling Roth (1899).

Affinities.—The 14 species of *Gymnothorax* Bloch recognized in Munro's Handbook (1957) are (prefixed numbers his list-numbers): 351* *G. cribroris*

Whitley, 1932; 352 *G. woodwardi* McCulloch, 1912; 353* *G. melanospilos* (Bleeker), 1805; 354* *G. margaritophorus* Bleeker, 1865; 355 *G. undulatus* Lacépède, 1803; 356* *G. chilospilus* Bleeker, 1865; 357* *G. petelli* (Bleeker), 1856; 358* *G. boschi* (Bleeker), 1853; 359* *G. flavimarginata* (Ruppell), 1828; 360* *G. pseudothyrsoidea* (Bleeker), 1852; 361* *G. longinquus* Whitley, 1948; 362 *G. priondon* Ogilby, 1895; 363 *G. favagineus* Bloch & Schneider, 1801; 364 *G. prasinus* (Richardson), 1848. Species here marked with an asterisk are known only (in respect of their Australian distribution) from Queensland (or Queensland and Torres Strait); while No. 363 is listed from Queensland and tropical Western Australia. It would seem unlikely any of these 10 forms should be met with in Tasmania; however, the possibility of the present fish being one of these species has not been dismissed, and they are further considered below.

Of the 14 species listed, 6—Nos 351, 352, 354, 356, 357, 361—differ sharply from the St Helens fish in two features, each of them having the postanal region longer than the preanal, and in possessing teeth on the vomer: 2 other species, Nos 358, 359, which more closely approach our specimen in having the postanal only slightly longer than, or equal to, the preanal length are ruled out by having vomerine teeth (as well as by other details of dentition), by the much higher fins, and by coloration. Of the remaining 6 species, 3 not known south of Queensland and tropical Western Australia—Nos 353, 360, 363—include 2 (360, 363) with vomerine teeth, the former being further distinguished by the very high fins, the latter by the single series of teeth in the lower jaw and the characteristic coloration; while No. 353, in which tail is equal to, or longer than, trunk, has the teeth in single series in both jaws.

The 3 species still to be noticed, the only ones reported in eastern Australian waters south of Queensland, call for special consideration. From No 355, *G. undulatus* (W.A., N.T., Qld, Torres Strait, North N.S.W.) *G. leecote* differs in having combined head and trunk longer than tail (*cf.* tail equal to, or ½ head longer than, head and trunk together), very much lower fins, in lower jaw two rows (*cf.* one row) of teeth, much more convex snout, coloration (dark spots, where they occur, not in longitudinal rows, and much smaller than eye in *G. leecote*). From No. 362, *G. prionodon* (N.S.W.), which it resembles somewhat in its general ground color and in having dark streaks on the throat, also in having at least indications of seration on teeth of the upper jaw, it differs in having trunk 1.25 (*cf.* 1.12) in tail and length of gill slit 1.7 (*cf.* less than) eye, in possessing biserial, instead of uniserial, teeth in both jaws and in lacking the 7 teeth on the palate, in lacking the gristle-like rounded or oblong, white or pale blue spots on the skin, and perhaps in larger size (815; *cf.* 322 of type; Munro, who normally records extreme length commonly encountered, gives 12¾ inches). From No. 364, *G. prasinus* (N.S.W., Vict., W.A., ?Qld, ?N.T.) it differs in having head and trunk longer (*cf.* less) than tail, head 3.8 (*cf.* 2.3-2.6) in trunk, dorsal origin further caudad, fewer mesial intermaxillary teeth.

Information as to whether or no the mouth can be completely closed (not closable in *G. leecote*) is not readily available for most of the species considered above, though the figures would perhaps suggest complete closure is possible in many, if not most, of the forms: this capacity is expressly noted in the account of No. 362 (Ogilby, 1895: 720).

Family SYNGNATHIDAE

Genus **UROCAMPUS** Günther, 1870

Urocampus carinirostris Castelnau, 1872

Urocampus carinirostris Castelnau, 1872, *Proc. Zool. Acclim. Soc. Vict.*, 1: 200. Type locality: Melbourne Markets.

Urocampus coelorhynchus Günther, 1873, *Journ. Mus. Godef.*, 1, 2: 103. Type locality: Sydney.

Tasmanian status.—This species is not credited to Tasmania in the Check List (McCulloch, 1929: 92), though, as pointed out in these Observations (1939), it had been listed earlier by Lord & Scott (1924: 39) on specimens secured at Table Cape [Wellington], Tasmania: in the Handbook (Munro, 1958: 88, fig. 615) it is recorded for all States except South Australia.

Material.—The present notes relate to (α) 12 specimens (1 distally imperfect), *Lt* 66.0-80.3, $\bar{x}$ 71.65 ± 1.21, σ 4.03 ± 0.86, *V* 5.6 ± 1.2; (β) 5 separately bottled, more heavily pigmented individuals, *Lt* 67.4-80.2, $\bar{x}$ 73.72 ± 1.82, σ 4.08 ± 1.29, *V* 5.5 ± 1.8—all dredged, as one collection, on 4th May 1963 by Mr B. C. Mollison in Carlton River, Pembroke among *Zostera sp.* For (α) and (β) pooled we find *Lt* 66.0-80.3, $\bar{x}$ 72.29 ± 1.00, σ 4.00 ± 0.71, *V* 5.5 + 0.98.

For both (α) and pooled (ϕ) and (β) the *Lt* distribution approximates the normal, the number of individuals lying within the range $\bar{x} \pm \sigma$ being 7, 10, respectively (expected 7.5, 10.9).

Values for conspectus items.—A conspectus of Tasmanian syngnathids (Scott, 1961: 58) recorded, for the listed species, the known ranges for 4 meristic features and 4 body ratios; the maximum total length; character of rostral crest; presence or absence of opercular keel: and as fresh data for various forms become available they are being noted in these contributions. For the present material the entries are as follows (values as set out in conspectus in parentheses). Total rings 9-10 + 53-59 (8-9 + 49: but an overlooked count by McCulloch (1910: 317) gives '50-53 (rarely 43)'), $\bar{x}$ 9.29 ± 0.11 + 55.62 ± 1.01. Subdorsal rings, dorsal beginning at from 0.9 (*i.e.*, at 9/10 of anteroposterior extension, starting from front of annulus) of 6th to 0.7 of 8th caudal ring; ending at from 0.8 of 10th to 0.6 of 12th ring (caudal 6th or 7th-caudal 11th or 12th). Brood rings, no data (subcaudal). Dorsal rays 12-14 (12-14), $\bar{x}$ 13.71 ± 0.14. Eye in snout 1.90-2.30 (1.3), $\bar{x}$ 2.07 ± 0.026. Snout in head 2.83-3.33 (2.8-3.3) $\bar{x}$ 3.01 ± 0.029. Head in trunk 1.58-2.29 (1.5-2.5), $\bar{x}$ 1.96 ± 0.049. Trunk in tail 3.42-5.34 (3.3-3.7), $\bar{x}$ 4.10 ± 0.23. The rostral crest is as described in the conspectus: the opercular keel extends from about ¾ of, to the full, length of the opercle. No obvious explanation

presents itself for the curiously high values for eye in snout among the present material, the below-average size of most of the specimens of which would suggest the probability rather of a divergence in the opposite sense.

The frequency distribution of the trunk annuli is 9 (12 specimens), 10 (5); of the caudal 53 (1), 54 (3), 55 (5), 56 (3), 57 (1), 58 (2), 59 (1): of the dorsal rays 12 (1), 13 (3), 14 (13), with, it is to be noted, classes below, but not above, the mode. For these three counts the coefficients of variation, *V*, are 4.9 ± 0.85, 2.9 ± 0.51, 4.2 ± 0.71, respectively —for some discussion of the magnitude of *V* expected in linear body measurements of biologically homogeneous samples see Part VI of these Observations (1953: 143), and references there to results reported by Simpson & Roe (1939) and Haldane (1952): the present figures suggest the possibility that comparable magnitudes of *V* (Simpson & Roe found the great majority of their entries lay between 4 and 10, with 5 or 6 as 'good average values') may characterize meristic data from reasonably homogeneous (possibly all) populations. (See also below, under *Clinus perspicillatus*, where *V*'s of *TLs* are examined.)

It will be seen the present data transgress the conspectus ranges for body rings, caudal rings, eye in snout, trunk in tail, in all cases at the upper extreme; and extend the recorded spread of subdorsal rays by one annulus caudad for the origin, and by one annulus cephalad for the termination, of the series.

Relative growth of certain regions.—Data previously presented (1964, Table I) for a small sample of *Syngnathus curtirostris* Castelnau, 1871 indicate that in that pipefish preanal length, expressed as a fraction of total length, tends to decrease with increasing overall size; the values of length to vent, as *TLt*, for 7 individuals of *Lt* 58.4-100.0, with specimens arranged in ascending order of magnitude of *Lt*, being 360, 353, 347, 346, 343, 342, 341. These values yield r — 0.994 (z 2.903), t 20.93.** For the two segments of preanal length—trunk length, head length—we find r — 0.965 (z 2.014), t 21.96**; r — 0.870 (z 1.333), t 3.95*, respectively. The same tendency for the precaudal region to account, as the fish continues to grow, for a progressively smaller proportion of the total length appears to be manifested in a very small sample of 4 specimens of *S. tuckeri* Scott, 1942, of *Lt* range 95.6-137.9 (1964, Table III), though only the whole preanal length yields a correlation statistically significant (r — 0.992, z 2.759, t 11.22**), the values for head, trunk being r — 0.771, z 1.023, t 1.71, r — 0.880, z 1.366, t 1.89, respectively. Rather surprisingly, an investigation of sample (*a*) (11 specimens) of the present series shows a positive correlation between *Lt* and each of the three dimensions, preanal length, trunk length, head length, as *TLt*, the first two being formally significant: the relevant magnitudes are r + 0.613, z 0.682, t 2.33*, r + 0.662, z 0.797, t 2.65*; r + 0.406, z 0.431, t 1.38.

For sample (*a*) the regression equation of preanal length, *Y*, on total length, *X* (both dimensions in mm) is

$$Y = 0.4753\ X - 14.74;\ t = 4.02^{**}.$$

That for trunk length on total length is

$$Y = 0.4387\ X - 18.59;\ t = 4.86^{**}.$$

That for head length on total length is

$$Y = 0.05146\ X + 2.80;\ t = 2.85^{*}.$$

Family CLINIDAE

Seven species are known to occur locally: (*a*) *Tripterygion* Risso, 1826, (1) *T. clarkei* (Morton), 1887; (*b*) *Gillias* Evermann & Marsh, 1900, (2) *G. macleayanus* (Lucas), 1891; (*c*) *Cristiceps* Cuvier & Valenciennes, 1836, (3) *C. australis* Cuvier & Valenciennes, 1836; (*d*) *Petraïtes* Ogilby, 1885, (4) *P. forsteri* (Castelnau), 1872, (5) *P. johnstoni* (Saville-Kent), 1886; (*e*) *Clinus* Cuvier, 1816, (6) *C. perspicillatus* Cuvier & Valenciennes, 1836, (7) *C. pueliarum* Scott, 1955.

Species (1) appears in the Check List under *Gillias*, (4) under *Cristiceps*, and, as a separate entry, under *Petraïtes incertus* McCulloch, 1915, (5) under *Clinus*—for present generic attributions see Scott (1939). Whitley (1956: 261) suggests (7) is identical with *Clinus marmoratus* Klunzinger, 1872, of which latter species he earlier gave the first figure (1941, fig. 25): whether or no this identification be accepted, the name *C. puellarum* stands, since, as Whitley points out, Klunzinger's name is preoccupied by *Clinus marmoratus* Castelnau, *Mem. Poiss. Afr. Austr.*, 1861, p. 52, from Table Bay, South Africa.

Another species, (8) *Petraïtes heptaeolus* Ogilby, 1885 is here added to the Tasmanian fauna. Species (1)-(7) have been keyed in an earlier contribution (1955: 137). The newcomer enters that key at section D, which includes species (4) and (5). From these it is readily separated by the lower dorsal count, iii, xxv-xxvi, 1 + 2 (*cf.* iii, xxviii-xxix, 4-5 for (4) and ii-iii, xxxii-xxxiv, 5-6 for (5)) and smaller number of soft anal rays, 17-20 (*cf.* 23-24, 25-27); also at sight by the presence near the posterior ends of the dorsal and anal of 2 oppositely placed particularly wide interradial spaces, the interval, filled with clear membrane, occurring in both fins between the antepenultimate and penultimate rays, an arrangement in sharp contrast to that found in the other species in both of which the (more numerous) dorsal soft rays and anal soft rays near the termination of the fin are inserted at subequal distances from one another.

Genus **PETRAÏTES** Ogilby, 1865

Petraïtes heptaeolus Ogilby, 1885

Petraïtes heptaeolus Ogilby, 1885, *Proc. Linn. Soc. N.S.W.*, x: 225 [as *nom. nud.* on p. 10]. Type locality: Port Jackson.

Cristiceps wilsoni Lucas, 1890, *Proc. Roy. Soc. Vict.* (n.s.), iii: 10, pl. iii, fig. 1. Type locality: Port Phillip, Victoria.

Record.—First record for Tasmania provided by 2 specimens, (*a*) *Ls* 44.7, *Lt* 53.9, (*b*) *Ls* 50.1, *Lt* 60.2 obtained at Green's Beach, Devon by Mr R. H. Green on 14th January 1962 (Queen Victoria Museum Reg. No. 1962: 5: 4). In dimensions and counts below (*a*) is cited first: entries in parentheses relate to Ogilby's type 3 3/10 inches in length.

Fin counts.—D. iii, xxvi, 1 + 2; iii, xxvii, 1 + 2. A. ii, 21; ii, 21. P. 11; 11. V. 3; 3. C. 10; 10. The original description gives V 1/3, an evident error (Lucas correctly has V. 3). The outer two pelvic rays exhibit a closer approximation to equality than those of most local clinids; the innermost ray extends beyond the level of point of bifurcation of the other two, a condition encountered also in *Petraïtes forsteri* and *Petraïtes johnstoni,* but not in *Clinus perspicillatus, Clinus puellarum,* or *Cristiceps australis.* Ogilby's account has A. 2/18-2, this notation being devised to call attention to the notably wide membranous interval separating the last two rays from the rest: the occurrence of oppositely placed spacings in the soft dorsal and anal rays in this form appears not to be paralleled in any common Australian clinid.

Proportions.—Head 4.1, 4.1 (5.2); caudal 5.9, 6.0 (6.6); height 4.1, 4.1 (4.6); length to vent 2.8, 2.8(—): in total length. Eye 4.4, 4.5 (3.8); pectoral 1.3, 1.4 (1.4); ventral 1.6, 1.7 (1.4): in head. Snout 0.6, 0.6 (half) eye; or 7.3 7.5 (about 7.2) in head. Interorbital 0.6, 0.6 (0.4) eye. Middle spine of first dorsal 1.9, 2.1 (—); longest (last) spine of second dorsal 1.9, 1.8 (—); longest (antepenultimate) anal ray 1.9, 1.9 (—): in head.

Remarks.—In his revision McCulloch states 'There seems to me to be little doubt that *Cristiceps wilsoni,* Lucas, must be included under this heading, the only apparent difference lying in a greater range of variation in the number of spines and rays in the dorsal and anal (D. iii, xxiv-xxviii; 1 + 2. A. ii; 17-21) of the Victorian species, than in any I have seen from New South Wales'. McCulloch's own counts are D. iii, xxv-xxvii; 1 +2. A. ii, 17-20; his upper extremes being the numbers found in the type specimen. Our specimens fall within McCulloch's dorsal range; but both transgress his upper anal limit, equalling the highest value recorded by Lucas (1891: 10) for his species.

There are about 25 contiguous tubules in the subhorizontal initial segment of the lateral line, 5-6 in the descending segment, and about 26-28, set progressively further apart, in the segment along middle of flank. An auriform membranous lobe, with subparallel marginal and inframarginal ridges, is attached superiorly to upper angle of operculum, inferiorly to base of uppermost pectoral ray; a backward extension of the branchiostegal membrane, enclosing tips of 5th and 6th branchiostegal rays, partly overlies it.

The original descriptions of Ogilby and Lucas and the account by McCulloch (1908: 41) all fail to provide a satisfactory picture of the tentacles—structures of diagnostic significance in this group. The rostral tentacle ('fringed, and widened out at the tip', Ogilby; 'small, jointed', Lucas; 'branched', McCulloch) follows a pattern found in most other species: it consists of a cylinder (whose height is here about twice its diameter), from the hind part of the rim of which rises a single leaf-like lobe, subequal in height to the cylinder, and of somewhat variable form, usually obovate or lanceolate, occasionally somewhat panduriform. The orbital tentacle ('single, simple, small', Ogilby; 'simple', Lucas; 'broad, fringed', McCulloch) is quite different from that of any other local clinid. In our specimens it is a simple much-flattened pointed lobe, about thrice as long as wide, rather broadly attached, the inner half of paper-thinness, with a more or less evenly convex border, the outer half somewhat thickened, largely owing to the presence (in its most pronounced form basally) of a longitudinal ridge, somewhat suggestive of the midrib of a leaf, but placed some what asymmetrically being further from the inner than from the outer margin of the lamina, the latter of which is convex throughout most of its length but briefly incurved basally: this tentacle is between two and three times as long as that on the snout, or about $\frac{3}{4}$ an eye-diameter.

Genus **CLINUS** Cuvier, 1816

Clinus perspicillatus Cuvier & Valenciennes, 1836

Clinus perspicillatus Cuvier & Valenciennes, 1836, Hist. Nat. Poiss., xi: 372. Type locality: Westernport, Victoria (Quoy & Gaimard).

Clinus despicillatus Richardson, 1839, *Proc. Zool. Soc. Lond.*: 97. Type locality: Port Arthur, Tasmania.

Fin counts.—The total number of rays (including the 2 spines) in the anal, as hitherto reported, appears to be 25-28 (*cf* Scott, 1962: 253). One specimen in a series of 11 collected by Cameron Scott at Taroona, Buckingham in December 1963 falls well below the recognized minimum with 23: totals for the other individuals are 25 (1), 26 (3), 27 (6). The accepted figures for the dorsal are iii, xxxii-xxxiv, 3-5. In the present sample we find iii, xxxii, 5 (2); iii, xxxiii, 4 (5); iii, xxxiv, 4 (2); iii, xxxiv, 5 (1); iii, xxxv, 4 (1), the last entry exceeding by one the recorded number of spines in the second dorsal.

The number of pectoral rays is usually given as 11-12; but here 1 fish has 13, 6 have 14, 3 have 15 (in all 10 cases in both fins), while 1 has 13 in left fin, 14 in right. Caudal rays number 12 (2), 13 (1), 14 (8).

Proportions.—Some proportions, expressed as *TLs,* are set out in Table I. As a contribution towards an answer to the question, what order of variability can be looked for in such values, the coefficient of variation, *V,* has been calculated for those 9 dimensions the *TLs* entries for which disclose no obvious sign of correlation with *Ls.* It will be seen the values for the 8 items other than *Lt* range from 5.2 to 12.2 (mean 7.10). It is of interest to note that these values are closely comparable with those that may be expected for absolute linear measurements of organs and morphologically significant body regions in populations homogeneous for age (and, if relevant, for sex)—*cf.* discussion on magnitude of *V*'s for meristic characters under *Urocampus carinirostris,* above. Higher values for raw measurements would of course be expected in the present sample, which, with an *Ls* range of 31.0-137.8 ($\bar{x}$ 97.88 ± 8.74) is a decidedly heterogeneous one: it is found that, for *Ls,* V = 29.6 ± 6.32; while for the 8 entries noted above *V* = 27.8-35.8, $\bar{x}$ = 31.02.

Quick tests point to the likelihood of the distribution of the population in respect of *Ls* being approximately normal. Within the range $\bar{x} \pm \sigma$

there occur 8 individuals (expected 7.5). Again, an estimate of the standard deviation for a random sample of the relevant size ($n = 11$) is 33.66, with 29.00 found.

Inspection of Table I suggests the existence in the cases of eye and length of ventral of a significant correlation between organ size and overall length; and correlation coefficients have been calculated for these two features. For diameter of eye and *Ls* we find r — 0.843, z 1.232, t 4.71**; for length of ventral and *LS*, r + 0.908, z 1.522, t 6.50**.

For the 19 specimens of this species incidentally noted below as being collected, by the rotenoning of two rock pools at Green's Beach, in association with *Ophiclinus gabrieli*, the *Ls* specification is: range 37.9-71.8, $\bar{x}$ 57.26 ± 2.09, σ 9.09 ± 1.47, V 15.9 ± 2.6. The number of individuals within the range $\bar{x} \pm \sigma$ is 13, which is the number expected in a normal distribution.

TABLE I

Clinus perspicillatus Cuvier & Valenciennes, 1836. Dimensions expressed as thousands of standard length (*TLs*), together with coefficient of variation (*V*) of *TLs* values, of 11 specimens (standard length 31.0-137.8 mm) from Taroona, Buckingham, Tasmania

Dimension	*TLs*											
	(*a*) 31.0	(*b*) 72.0	(*c*) 81.0	(*d*) 88.5	(*e*) 90.6	(*f*) 104.9	(*g*) 106.6	(*h*) 107.7	(*i*) 125.5	(*j*) 131.1	(*k*) 137.8	*V* (of *TLs*)
Total length	1165	1164	1178	1162	1129	1152	1160	1162	1181	1159	1137	1.3
Head: total; soft	291	242	235	249	270	253	251	252	255	248	257	5.6
Head: without opercular flap; hard	245	221	199	214	238	217	219	221	208	221	216	5.6
Snout	42	40	42	46	50	44	47	45	54	46	47	8.2
Eye	94	62	56	59	65	56	56	57	57	53	52	
Interorbital	35	28	26	27	30	27	23	27	31	34	33	12.2
Length to vent	465	469	467	419	397	418	453	409	441	465	472	6.0
Length of pectoral	190	168	184	171	196	172	173	181	174	192	171	5.2
Length of ventral	194	167	168	168	172	154	150	149	146	157	147	....
Depth at anal origin	171	171	198	192	188	219	197	176	207	198	192	7.4
Depth of caudal peduncle	61	60	53	59	54	61	56	59	49	54	55	6.5

Family Ophiclinidae

Two species of *Ophiclinus* Castelnau, 1872 (emended in 1873 by Castelnau to *Ophioclinus*) appear on the State list: (1) *O. greeni* Scott, 1936 (type locality: Lady Lucy Beach, Low Head [Dorset], Northern Tasmania); (2) *O. gracilis* Waite, 1906 (type locality: Long Bay, near Sydney, New South Wales; recorded for Tasmania by Olsen (1958), who notes it is a common food for small sharks in George Bay, Dorset/Cornwall). Another species, (3) *O. gabrieli* Waite, 1906 (type locality: Victoria; and in the Check List not noted from any other State) is here added.

Whitley (1941) identifies (2) with *Sticharium dorsale* Günther, 1867, the Ophiclinidae thus becoming the Stichariidae. *Sticharium* is either identical with or closely allied to *Ophiclinus*. Difficulties in the way of identifying it with Castelnau's genus include: 'naked or with scarcely a trace of scales' (in *O. gracilis*, a suggested synonym of the type species of *Sticharium*, scales are readily observable—a statement not true, by the way, of all species of *Ophiclinus*); 'palate apparently toothless' (vomer toothed); dorsal fin 'formed by pungent spines only' (one jointed ray at posterior end). As regards the possible identity of Waite's species with Günther's, it is to be noted (*a*) the former has D. xliii + 1, A. iii, 29, the latter D. xli, A. ii, 36; (*b*) ventrals are equal to, or a trifle shorter than pectorals, as against Günther's 'ventrals much longer than the pectorals': such divergences do not appear readily reconcilable—though of course the pertinent question arises, if *S. dorsale* is not *O. gracilis*, what is it? (possibly some other species at present attributed to *Ophiclinus; e.g., O. gabrieli*?) Günther's entry 'a broad white band runs along the upper surface of the head and back' describes well the condition found in many examples of *O. gracilis;* however, a light-colored middorsal stripe is encountered in some other species of the genus.

Key to Ophiclinidae Recorded from Tasmania

1 Dorsal beginning above end of operculum. Dorsal origin not well defined, a triangular membrane leading up to 1st spine; first few spines progressively increasing noticeably in length, height of 1st < 2/3 (≐ ⅔) that of 4th. D. li-liii, 1. Anal composed solely of soft rays .... *O. gabrieli*

1 Dorsal beginning in advance of end of operculum (the latter about below 3rd dorsal spine). Dorsal origin well defined, no triangular membrane leading up to 1st spine; first few spines progressively increasing only slightly in length, height of 1st ≥ that of 4th D. xliii-xlix, 1. Anal with 3 small spines 2

2 { D. xliii, 1. Lateral line strongly arched; markedly bent down posteriorly, its tip about on the horizontal line joining upper border of eye and upper angle of caudal peduncle .... *O. gracilis*
D. xlvi-xlix, 1. Lateral line nearly straight; not, or scarcely, continued obliquely downwards posteriorly, its tip equidistant from dorsal profile and the horizontal line joining upper border of eye and upper angle of caudal peduncle .... *O. greeni*

All Tasmania species belong to the group in *Ophiclinus* possessing a well-defined lateral line and having pectoral longer than eye; and to the section of this group in which the vomerine teeth are pointed and in rows.

Genus **OPHICLINUS** Castelnau, 1872

Ophiclinus gabrieli Waite, 1906

Ophiclinus gabrieli Waite, 1906, *Rec. Aust. Mus.*, vi, 3: 208, pl. xxxvi, fig. 7 (in legend of plate appears as fig. 6). Type locality: Victoria.

Record.—Two examples, (*a*) *Ls* 45.5, *Lt* 51.2, (*b*) *Ls* 54.1, *Lt* 61.1, (Queen Victoria Museum Reg. No. 1964: 5: 16) are among 40 fish obtained by Mr R. H. Green by the rotenoning of two rock pools at Green's Beach, Devon, on 13th September 1964. The other items in the collection are *Clinus perspicillatus* Cuvier & Valenciennes, 1836 (19 specimens—see further under that species), *Pictiblennius tasmanianus* (Richardson), 1849 (12 specimens: *Ls* specification, range 24.9-58.0, $\bar{x}$ 42.27 ± 2.60, σ 9.00 ± 1.84, *V* 21.3 ± 4.4), *Alabes rufus* (Macleay), 1881 (7: *Lt* specification, range 46.0-31.5, $\bar{x}$ 62.17 ± 4.28, σ 11.33 ± 3.03, *V* 18.23 ± 4.9).

Proportions.—In general these examples agree well with the original description. Our specimens are, however, smaller than Waite's—2 females carrying young and an adult male, the largest 102 in length—and exhibit some differences in proportion. For ratios noted by him the values for (*a*), (*b*), and, in parentheses, the Victorian fish (for which no ranges are recorded) are as follows. Head 4.6, 4.3 (5.3); depth at origin of anal 8.8, 8.3 (7.5); caudal 8.0, 7.7 (8.0): in total length. Eye 4.8, 4.6 (4.2); middle pectoral rays 2.4, 2.4 (2.4); ventral 1.5, 1.7 (a little less than twice): in head. Depth of caudal peduncle 2.0, 2.2 (2.5) in depth of body. Interorbital 1.8, 2.0 (twice) snout or 1.3, 1.2 (less than twice) in eye. Length to vent 2.3, 2.3 (from figure 2.5) in total length.

Fin counts.—D. (*a*) lii, 1; (*b*) lii, 1 (*cf* li + 1 in type). A. 36, 35 (36). P. left 11, right 12; 12, 12 (12). V. 2, 2 (2). C. 3 + 11 + 3, 2 + 11 + 3 (11 + 4).

Coloration.—A narrow (in (*a*) very narrow) stripe of warm brownish (*a*) or deep salmon (*b*) borders either side of the dorsal fin which is concolorous with it: this continues forward, increasing somewhat in width as it advances, to level of hind border of eye. Between this stripe and a line joining lower border of eye and upper end of caudal base dark, virtually uniform brown (tip of lateral line is situated in the upper one-fourth or one-third of this band); below this line lighter brown mottled with darker. Anteriorly the darkest of the three regions can be regarded as a dark band passing backwards from eye, its width here being an eye-diameter. Dorsal warm brownish (*a*) or deep salmon (*b*), microscopically punctulate, but otherwise save for a discontinuous very narrow external border of deep flesh color. Anal somewhat darker than dorsal, with some lighter mottling, particularly in the posterior half. Pectoral with basal half (*a*), or one-third (*b*), dark brownish with one or two small lighter spots: rest of fin brownish with small whitish spots (*a*) or ashen with some dusky marbling (*b*). Pelvics white or flesh color, with some duskiness up to the bifurcation of the rays.

Ophiclinus greeni Scott, 1936

Ophiclinus greeni Scott, 1936, *Pap. Proc. Roy. Soc. Tasm.* (1935): 114, fig. 1. Type locality: Lady Lucy Beach, Low Head [Dorset], Northern Tasmania.

New material.—Three examples, (*a*) *Ls* 77.4, *Lt* 83.0, (*b*) *Ls* 78.1, *Lt* 85.1 (male); (*c*) *Ls* 82.0, *Lt* 89.9 (male) (Queen Victoria Museum Reg. No. 1964: 5: 18) are included in a small collection of fish secured by Mr R. H. Green in December 1963 in rock pools on the reef at Green's Beach, Devon: this beach and the type locality lie near the mouth of the Tamar estuary, on the west and east side, respectively. Other fish collected at the same time comprise *Callogobius hasseltii* (Bleeker), 1851 (3 specimens, dealt with elsewhere in this paper); *Aspasmogaster tasmaniensis* Günther, 1861 ((*a*) *Ls* 60.0, *Lt* 70.0; (*b*) *Ls* 67.9, *Lt* 78.1); *Clinus perspicillatus* Cuvier & Valenciennes, 1836 (*Ls* 83.3, *Lt* 97.0); *Pictiblennius tasmanianus* (Richardson), 1849 ((*a*) *Ls* 49.0 *Lt* 58.1; (*b*) 52.7, *Lt* 63.8; (*c*) *Ls* 54.9, *Lt* 66.0).

These provide some interesting meristic and other metrical data for comparison with the known magnitudes based on the 1936 type material (holotype, *Ls* 40.5, *Lt* 44.6; 2 paratypes, *Ls* 31.9, 34.3 *Lt* 45.5, 49.8) and 2 larger individuals, *Ls* 56.5, 68.0, *Lt* 62.0, 75.0 from the mouth of the Currie River, in the same county as the type locality (Scott, 1939): their color patterns show features not previously encountered.

Fin counts.—The known range for the dorsal now becomes xlvi-xlix, 1 (previously xlviii-xlix, 1); for the anal iii 29-32 (iii 31-32): ventral is invariable at 2, and caudal at 13 main rays (with minor rays ranging from 1 to 3 both superiorly and inferiorly); and pectoral range remains unchanged at 11-12.

Proportions.—In this paragraph the present specimens are arranged in ascending order of magnitude of *Ls*: for the first 8 items entries in parentheses represent range of the 1936 and the 1939 specimens pooled, while for the remaining 6 items the range is that of the type material only. Depth 7.8, 8.0, 8.2 (7.1-8.8) in *Lt;* 7.2, 7.4, 7.5 (6.4-8.1) in *Ls*: depth at 1st anal ray 8.3, 8.5, 8.5 (7.7-9.3) in *Lt*; 7.7, 7.7, 7.8 (6.9-8.4) in *Ls*. Head 5.0, 4.7, 4.9 (4.9-6.4) in *Lt*; 4.6, 4.3, 4.4 (4.4-5.8) in *Ls*. Eye 6.7, 7.2, 7.1 (5.3-6.5) in head; 1.4, 1.6, 1.5 (1.2-1.5) in snout; 1.4, 1.3, 1.2 (1.1-1.2) times interocular distance. Head and trunk 1.1, 1.4, 1.3 (1.1-1.3) in tail without caudal fin. Pectoral 1.9,

1.9, 2.1 (1.7-1.9); pelvic 1.9, 1.8, 1.6 (1.4-1.8): in head. Caudal 3.0, 2.6, 2.3 (1.9-2.1) in head; 13.8, 11.1, 9.8 (8.8-10.6) in *Ls*.

Specimen (*a*) presents the same general color pattern as the holotype. In (*b*) the dorsal and anal are wholly white (except for a row of 5 dark basal spots about 1 mm in diameter on the former) to about a head-length caudad of the vent, being behind this almost uniform brown: a narrow white band on the back borders either side of the white anterior $\frac{2}{3}$ of the dorsal. In (*c*) the whole dorsal is an even off-white, minutely punctulated with brownish throughout; with, in its last one-third, three or four brownish bars, increasingly deeper in color and more sharply defined caudad: a narrow whitish stripe runs along either side of the anterior $\frac{3}{4}$ of base of fin.

In the largest and smallest individuals the penis is extruded—a whitish subcylindrical organ with wide simple transverse slit at the downwardly and forwardly directed tip.

Status.—This species is closely allied to, and may possibly be identical with, *O. gracilis*. Of the chief differences from Waite's species noted as characterizing the type material (holotype, *Ls* 40.5, *Lt* 44.6, and 2 paratypes, *Ls* 31.9, *Lt* 45.5, *Ls* 34.3, *Lt* 49.8)—(*a*) 'consistently greater number of dorsal spines and' (*b*) 'anal rays'; (*c*) 'rather fewer pectoral rays'; (*d*) 'origin of anal below about 20th, instead of 17th, dorsal spine'; (*e*) 'lateral line nearly straight, not, or scarcely, continued obliquely downwards posteriorly'—(*a*), (*c*) (which is probably of little significance), and (*e*) hold good for the present material. At 29-30, anal rays fall below the counts for the types (31-32), and overlap the count (29) for *O. gracilis*. As regards (*d*): the anal originates in these specimens below the 19th, 18th, 19th dorsal spine. The lateral line is in all 3 cases nearly straight and almost exactly conformable with that described for all the type material and figured for the holotype—the situation is in marked contrast to that in *O. gracilis*, in which the lateral line is described as 'strongly arched' and is clearly so depicted (Waite, 1906, pl. xxxvi, fig. 6) in the illustration of the holotype. In *O. gracilis* the last few tubules turn down sufficiently to reach to or slightly beyond, the light-colored lower portion of the flank: in *O. greeni* the last tubule is nearer to the dorsal profile than to the line of junction between the upper dark and lower light zones of the flank. It is possible the character of the lateral line, together with the more numerous dorsal rays in the Tasmanian fish (in *O. greeni*, including the present material, which has extended the range downward, 46-49; in *O. gracilis* 43), may significantly differentiate the two forms.

Family Gobiidae

In Part XI of these Observations (1936) 6 gobies were listed from Tasmania (No. 1 in the enumeration below doubtful) and keyed: (*a*) *Rhinogobius* Gill, 1859, (1) *R. lateralis* (Macleay), 1881; (*b*) *Stigmatogobius* Bleeker, 1874, (2) *S. poicilosoma* (Bleeker), 1849; (*c*) *Nesogobius* Whitley, 1929, (3) *N. hinsbyi* (McCulloch & Ogilby), 1919; (*d*) *Arenigobius* Whitley, 1930, (4) *A. bifrenatus* (Kner), 1865, (5) *A. tasmaniensis* (Joshnston), 1883; (*e*) *Tasmanogobius* Scott, 1935, (6) *T. lordi* Scott, 1935. Of these the Check List (McCulloch, 1929) gives as Tasmanian (1), (3), (5), together with *Gobius tasmanicus* Whitley, 1929 [*ex* Johnston MS], which last species the present writer in a review of the Tasmanian gobies then known (1935) considered should be regarded as a synonym of (5).

An additional species, (*f*) *Callogobius* Bleeker, 1874, (7) *C. hasseltii* (Bleeker), 1851, hitherto known from New South Wales, Victoria, South Australia, Western Australia (McCulloch, 1929: 377), Queensland (Koumans, 1953: 99), and a wide range of extralimital localities (including India, Indonesia, Japan), is here recorded for this State. It may be distinguished at sight from all the species in the 1963 key by the presence on head and body of conspicuous crenulated ridges formed of confluent papillae.

Genus **GALLOGOBIUS** Bleeker, 1874

Callogobius hasseltii (Bleeker), 1851

Eleotris Hasseltii Bleeker, 1851, *Nat. Tijdschr. Ned. Indië*, 1: 253. Type locality: Anjer, Java.

Gobius mucosus Günther, 1872, *Proc. Zool. Soc. Lond.* (1871): 663, pl. lxiii, fig. A. Type locality: Adelaide.

Gobius depressus Ramsay & Ogilby, 1886, *Proc. Linn. Soc. N.S.W.* (2), 1, 1: 4. Type locality: Bottle and Glass Rocks, Port Jackson.

Callogobius hasseltii var. *mucosus* Günther. McCulloch & Ogilby, 1919, *Rec. Aust. Mus.*, xii, 10: 217, pl. xxxii, fig. 4.

Callogobius mucosus (Günther). McCulloch, 1929, *Aust. Mus. Mem.* V 111: 377. *Id.* Scott, 1962, Mar. and Fresh Water Fishes of S. Aust.: 240, unnumbered fig. on p. 240.

Callogobius hasseltii (Bleeker). Koumans, 1953, Fish. Indo-Aust. Arch. (Weber & De Beaufort), X: 98, fig. 20.

Record.—Three specimens, (*a*)-(*c*), *Ls* 66.0, 67.6, 68.0, *Lt* 81.3, 85.3, 85.6, respectively, were collected by Mr R. H. Green at Green's Beach, Devon in December 1963 (Queen Victoria Museum Reg. No. 1964: 5: 17): for other species secured at the same time see above under *Ophiclinus greeni*.

Fin formulae.—In their review of Australian Gobiidae McCulloch & Ogilby have for this species, which they treat as *C. hasseltii* var. *mucosus*: D. vi/11; A. 9; P. 16; V. i/5; C. 16. As for most other species their definitive description is based on a single individual (though they examined upwards of a hundred specimens from 4 Australian States), and no indication of variation in fin-counts is supplied. Koumans (1953: 98) gives D_1 VI; D_2 I. 9-10; A. I. 7-8; P. 16-18.

Of our specimens (*a*) and (*c*) have in second dorsal 12 rays (in (*a*) last split to base, the rami adherent), (*b*) 11; while (*a*) and (*c*) have 9 anal rays, (*b*) 10 (last divided nearly to base). Pectoral rays: (*a*) 14 (left), 16 (right); (*b*) 18; (*c*) 17. Caudal: all 16, plus several rudimentary rays above and below.

Comparative proportions.—Values in our material —sequence (*a*), (*b*), (*c*)—for those proportions recorded by McCulloch & Ogilby (their values in parentheses) are as follows. Depth 6.6, 6.4, 6.1 (5.7); head 3.6, 3.6, 3.4 (3.9) in *Ls*. Eye 1.7, 1.6, 1.5 in snout ('slightly shorter than snout'); snout 3.2, 3.6, 3.2 (3.5) in head. Interorbital 3.4, 3.3, 3.6 (about 4) in eye (this is bony interorbital; interocular 1.7, 1.1, 2.05). Breadth between pectorals 1.2, 1.0, 1.1 (equal to) depth there. Depth of caudal peduncle 3.0, 3.0, 2.9 (2); length of pectoral 1.2, 1.3, 1.4 (1) in head. Space between gill openings 2.1, 2.2, 1.7 (twice) eye. Fifth dorsal spine 1.1, 1.4, 1.1 (subequal to) postorbital head. Adpressed pectoral failing to reach vent, extending to level of end of 1st dorsal, origin of 2nd dorsal, last spine of 1st dorsal ('not quite reaching vertical of the vent'). Ventrals reaching 0.59, 0.59, 0.59 ('about two-thirds') of their distance from vent.

Coloration.—McCulloch & Ogilby observe 'the southern specimens are very dark with their markings obscurely defined, while those from Port Jackson and South-west Australia are often lighter and more or less conspicuously banded'. Comparable variation here occurs within the sample, (*c*) alone exhibiting the second type of coloration. The second dark cross-band below the anterior dorsal rays is represented in our material only by a dark spot in (*b*). Pelvics wholly whitish, except for basal interspinous membrane, which is more or less dusky; other fins all light-margined, the anal most extensively and conspicuously so.

Remarks.—Koumans makes no mention of, nor does the figure by Weber (1913, fig. 98) reproduced by him show, the characteristic chiefly subvertical crenulated (occasionally comb-like) ridges on the body; these are well depicted, however, in the figure (pl. xxii, fig. 4) in McCulloch & Ogilby (1919).

Family Tetraodontidae

Four species are known to occur in Tasmania: (*a*) *Tetraodon* Linné, 1758, (1) *T. armilla* McCulloch & Waite, 1915; (*b*) *Spheroides* Duméril, 1806, (2) *S. richei* (Fréminville), 1813, (3) *S. liosomus* Regan, 1909, (4) *S. hamiltoni* (Gray & Richardson), 1843. A key to these local species is given in Part XI of these Observations (1963: 26); in which contribution reasons are advanced for the inclusion in our faunal list of (4), not treated as Tasmanian in the Check List (McCulloch, 1929: 430). It may be noted that in his recent work on South Australian fishes Scott (1962) refers (2) to the genus *Contusus* Whitley, 1947, and apparently treats (3) as a synonym of *Gastrophysus glaber* Fréminville, 1873.

An additional species, (5) *T. firmamentum* Temminck & Schlegel, 1850—the distribution of which, as recognized in the Check List, is New South Wales, Victoria, New Zealand, Japan—is here recorded for this State. It is a rare form, occurring in deep water.

No new key to Tasmanian species seems called for, *T. firmamentum* being tenchantly separated from the 4 other species by its large number of dorsal and anal rays, 14 in each fin—a maximum of 11 in the dorsal being recorded for (1), (3), and one of 9 for (2), (4); with the anal total exceeding 9 only in (1), in which the normal count is 9-11.

Genus **TETRAODON** Linné, 1758

Tetraodon firmamentum Temminck & Schlegel, 1850

Tetraodon firmamentum Temminck & Schlegel, 1850, Faun. Japan Poiss.: 280, pl. cxxvi, fig. 2. Type locality: Japan.

Tetraodon gillbanksii Clarke, 1897, *Trans. N.Z. Inst.*, xxix: 245, pl. xiv. Type locality: Taranaki, New Zealand.

Record.—An example, *Ls* 237, *Lt* 302, was found washed up on the sand after a storm at Green's Beach, Devon by Mr J. Squires in July 1964 (Queen Victoria Museum Reg No. 1964: 5: 14).

Remarks.—The specimen, which is in a good state of preservation, agrees well with the original figure, reproduced by McCulloch (1927, pl. xliii, fig. 369*f*), the chief differences being: spines on the throat here extend further forward (to midway between levels of eye and snout-tip); the ventral silvery area does not curve upward beneath the eye, and is somewhat less clearly defined on the caudal peduncle than in the figure; the caudal bears, across the upper $\frac{1}{5}$ in the last $\frac{3}{4}$ of its length, an asymmetrically placed forwardly convex whitish cross-bar that is perhaps a purely individual variation.

The spines, which on the under surface and on much of the sides and backs are normally sheathed in, or distally project from, white fleshy vesicles, attain their greatest exposed length on the belly in the anterior $\frac{2}{3}$ of the interval between the levels of insertion of the pectoral and the anal. They are more nearly erect medially on the dorsum of the body and in a patch above the pectoral base than elsewhere. On the lower surface they wholly cease before the vent, and on the lateral surface only a scattered few extend behind the dorsal fin termination, and these are restricted to the anterior $\frac{1}{2}$ of the upper $\frac{1}{3}$ of the caudal peduncle. Spineless areas occur also immediately surrounding the other fin bases, encircling the eye, and near the tip of the snout.

Some Data on Catches at a Fishing Competition at George Town, Dorset, in December 1963

Catch records of Californian shark derbies by Herald, Schneebelli, Green & Innes (1960)—and earlier by the first author alone or jointly (references in the paper here cited)—bring to notice the interest attached to large-scale data provided by fishing competitions in general. The following notes made by the writer at a fishing competition held at George Town, Dorset on 7th December 1963 (the day fine and calm; official contestants about a hundred) record the range of species observed, along with some linear dimensions (mm) and weights (lb., oz.).

Prizes were offered for the heaviest specimen of: (*a*) 'bluehead', *Pseudolabrus tetricus* (Richardson), 1840 (1st *Ls* 392, *Lt* 468, wt 4 lb. 14 oz.; 2nd *Ls* 405, *Lt* 458, wt 4 lb. $2\frac{3}{4}$ oz.): (*b*) 'parrot fish', *P.*

fucicola (Richardson), 1840 (1st *Ls* 365, *Lt* 440, wt 3 lb. 8¾ oz.); (*c*) 'gurnard' *Ruboralga ergastulorum* (Richardson), 1842 (1st wt 1 lb. 11¼ oz., 2nd 1 lb. 7 oz.); (*d*) 'blackback salmon', *Arripis trutta* (Bloch & Schneider), 1801 (1st wt 2 lb. 6 oz.; 2nd 1 lb. 11¾ oz.); 'leatherjacket' of any species (1st *Meuschenia hippocrepis* (Quoy & Gaimard) 1821, wt 1 lb. 12 oz.; 2nd, another species, *Ls* 322, *Lt* 387, wt 1 lb. 11¾ oz.).

Sharks caught included: (*a*) gummy, *Mustelus antarcticus* Günther, 1870 (*Lt* 1253, wt 13 lb. 12¼ oz.; *Lt* 1230, wt 13 lb. 9¼ oz.); (*b*) Port Jackson shark, *Heterodontus portusjacksoni* (Meyer), 1793 (*Lt* 1098, wt 22 lb.); (*c*) 3 swell sharks, *Cephaloscyllium isabella laticeps* (Duméril), 1853 (not measured; subequal; estimated *Lt* 850-950: 7 adults previously noted in these Observations (1963: 4) have *Lt* 885-961, $\bar{x}$ 913.0 ± 9.16, showing the small coefficient of variation of 2.7).

Other fish submitted included short-finned eel, *Anguilla autralis occidentalis* Schmidt, 1928; barracouta, *Leionura atun* (Euphrasen), 1791; one specimen of butterfly perch, *Caesioperca lepidoptera* (Bloch & Schneider), 1801.

First and second prizes for the largest bag were won with 257 and 213 fish, in each case almost exclusively *Pseudolabrus fucicola* (here is reason to believe each entry represented the pooled catch of several anglers).

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NEW RECORDS OF MARINE MOLLUSCA FROM TASMANIA

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ABSTRACT

Recent collecting in southern Tasmania has produced three interesting species of marine molluscs not previously recorded from Tasmania. Two of these, Maoricolpus roseus (Quoy & Gaimard), and Paphirus largillierti (Philippi 1849), were previously know only from New Zealand. The third, Soletellina donacioides Reeve 1857, occurs in southern Australia. Except where otherwise stated, the specimens were collected by the author.

CLASS: GASTROPODA

Family: TURRITELLIDAE

Maoricolpus roseus (Quoy & Gaimard)
(Pl., fig. 1.)

Turritella rosea Quoy & Gaimard 1834, *Voy. Astrolabe* (iii), p. 136, pl. 55, f. 24-26.

This distinctive species, previously thought to be restricted to New Zealand, has been found in large numbers in the D'Entrecasteaux Channel, Southern Tasmania.

Localities:

(i) Two dead shells from the Macquarie Harbour area, West Coast, Tas., collected by A. M. Olsen. (Miss J. H. Macpherson—pers. comm.)

(ii) One dead shell collected near Gordon, D'Entrecasteaux Channel, in June 1963, by Mr. Ralph C. Robertson, Cygnet. (Tasmanian Museum No. 18328/E2804).

(iii) One worn specimen from Brabazon Point (locally known as One Tree Point) (T.M. 18399/E2864), and one from Randalls Bay, both in the Huon Estuary, collected in 1963 by Mr. R. C. Robertson.

(iv) Numerous live specimens dredged from D'Entrecasteaux Channel, from August to October, 1964 by Mr. John Farnell, Kettering. (Many of these specimens have been given to the Tasmanian Museum and the National Museum of Victoria by Mr. Robertson and Mr. Farnell. Live specimens have been kept under observation at the latter Museum.)

Remarks:

Powell (1961) states that the species is common in New Zealand, on sandy or muddy bottoms, in inter-tidal or shallow water. He mentions that where conditions are favourable, such as at Devonport, Auckland Harbour, the mollusc occurs in vast beds, in 6 to 8 fathoms, with several hundred individuals to each square yard.

Similarly Mr. Farnell, who has dredged for scallops in the D'Entrecasteaux Channel for many years, says that he has dredged this species from sandy or muddy bottoms throughout the Channel, in depths ranging from 2 to 10 fathoms, and in large quantities. However, no inter-tidal specimens have been recorded.

Dimensions of the Tasmanian specimens compare well with those of New Zealand specimens of Maoricolpus roseus given by Powell (1931, p. 100), and differ from those of Mr. roseus manukauensis Powell 1931.

Specimens from D'Entrecasteaux Channel, Tas.

Height	Diameter	Spire Angle
41.6 mm	14.0 mm	21 degrees
60.0 mm	17.8 mm	19 degrees
66.5 mm	21.4 mm	22 degrees
75.5 mm	23.2 mm	21 degrees

M. roseus roseus (New Zealand, various localities, from Powell, 1931).

Height	Diameter	Spire Angle
42.00 mm	14.00 mm	22 degrees
62.00 mm	18.25 mm	21 degrees
70.00 mm	21.50 mm	22 degrees
74.00 mm	22.50 mm	21 degrees

M. roseus manukauensis (Holotype)

Height	Diameter	Spire Angle
59.00 mm	13.00 mm	14 degrees

The colouring also is similar to that given by Suter (1913, p. 271) for New Zealand specimens—"yellowish or reddish-brown, faintly marbled with dark brown, the raised cinguli usually of darker brown".

M. roseus probably became established in the Channel from 20-40 years ago, since Mr. Farnell has specimens collected over 20 years ago, and the species was not recorded by W. M. May, who dredged for molluscs in the Channel in the 1920's. Judging by the number of specimens taken in his scallop dredges, Mr. Farnell believes that the species is rapidly increasing in numbers.

It is interesting that despite its abundance in relatively shallow water, dead shells are very rare on beaches. This may be due to the action of small hermit crabs which are common in dredged material from this area, and inhabit Maoricolpus and similar shells.

CLASS: PELECYPODA

Family: VENERIDAE

Paphirus largillierti (Philippi 1849)
(Pl., figs. 2, 3.)

Venus intermedia Q. & G. 1835, *Voy. Astrolabe* (iii), p. 526, pl. 84, f. 9, 10.

Paphia intermedia Q. & G. 1835: Suter 1913, *Manual N.Z. Moll.*, p. 995, pl. 61, f. 6a.

Venus largillierti Philippi 1847, *Zeitsch.f.Malak.*, p. 87.

Paphirus largillierti (Phil.), Finlay 1927, *Trans. N.Z. Inst.*, Vol. 57, p. 633.

Tapes fabagella Deshayes 1853, *Cat. Conch. Brit. Mus.*, p. 182. (For full synonymy see Suter 1913.)

This New Zealand species, described by Powell (1961) as being common on sandy beaches, has recently been found in southern Tasmania. It occurs on several sandy beaches in the Derwent Estuary, and is very common on the Spit, behind Gellibrand Point, Ralphs Bay. Sometimes large numbers are washed ashore at Long Point, Sandy Bay.

The first specimens brought to my notice were collected at Blackmans Bay by the Rev. P. Noonan in early 1963.

Localities:

(i) Blackmans Bay, Derwent Estuary. Several specimens collected in early 1963 and on 27th November, 1963 by Rev. P. Noonan. (T.M. Nos. 18326/E2802, 18736/E3130).

(ii) Richardsons Beach, Ralphs Bay, Derwent Estuary. Collected in early 1963 by Miss E. J. Howard.

(iii) Pirates Bay, Eaglehawk Neck. A single specimen, 7th November, 1963. (T.M. 18329/E2805).

(iv) Beaches at Sandy Bay, near Hobart, Derwent Estuary. Various dates from 14th December, 1963. Collected by Misses E. Aves and E. J. Howard, and the author. (T.M. collection).

(v) Mary Ann Beach, Derwent Estuary, October, 1964.

(vi) The Spit, Gellibrand Point, Ralphs Bay, Derwent Estuary. Numerous specimens collected 17th January, 1965. (T.M. E3849).

(All these specimens were dead shells.)

Remarks:

The colouring of the Tasmanian specimens agrees with that described for New Zealand shells by Suter (1913, p. 995), but there is considerable variation among the specimens. A fairly large shell from Eaglehawk Neck resembles young shells from other areas in being rather lightly built and having brown zig-zag markings, as described by Suter for young N.Z. specimens. The large shells from Sandy Bay and Ralphs Bay, however, are very robust, coarse shells with no zig-zag markings, but often with an olive-green epidermis. (It is interesting that Suter (p. 996) remarks that "specimens from the Auckland Islands are brown, very large and solid.").

Suter (1913) and Powell (1961 pl. 15) give 57 mm. x 41 mm. as the dimensions of P. largillierti. This agrees with the local specimens, one from Sandy Bay measuring 59.3 mm. x 42.9 mm. The largest shell collected is 61.3 mm. x 44.0 mm.

The numbers of P. largillierti present, and their size and wide distribution in the Derwent Estuary indicate that the species has been established for some time. The approximate age of the largest shells, estimated by counting annual growth rings (Powell 1961, p. 197), varies from 8 to 10 years.

The robust specimens common at Sandy Bay bear a superficial resemblance to Katelysia rhytiphora Lamy 1937, and this may be the reason they have been overlooked by recent workers. However, they are oval-oblong in shape, rather than the wedge-shape of typical K. rhytiphora. Young specimens also may resemble Pullastra fabagella (Deshayes 1853), a species with which they have been confused in New Zealand (Marwick 1927, p. 633), and which occurs at the same localities in Tasmania.

Kershaw (1958, p. 68) says "Katelysia scalarina is generally found, and at Sandy Bay near Hobart is a robust shell associated with K. corrugata", (= K. rhytiphora). Again he says (p. 80) "near the entrance to Pipe Clay Lagoon a typical sandy exposed beach fauna was obtained . . . . A similar fauna exists at Sandy Bay near Hobart, and here Katelysia scalarina and K. corrugata are robust shells".

May (1923) lists K. scalarina as very common in sheltered inlets, and K. rhytiphora as common in sheltered bays, and Nielsen (1963, p. 224) says K. scalarina is usually found in quiet, sheltered sandy bays. Kershaw also describes K. scalarina as a "sheltered" bivalve (p. 79) and in Table 2 (p. 92), lists both K. scalarina and K. corrugata (= K. rhytiphora) as occurring only in sheltered areas in the south. It is therefore surprising that he includes these species in a "typical sandy exposed beach fauna" such as he states exists at Sandy Bay.

The writer has found no specimens of Katelysia spp. at Sandy Bay, and these facts suggest that Kershaw may have mistaken specimens of P. largillierti for Katelysia spp.

Family: SANGUINOLARIIDAE

Soletellina donacioides Reeve 1857.
(Pl., Fig. 4.)

Soletellina donacioides Reeve 1857, *Conch. Icon.*, 10, pl. 3, sp. 11.

Flavomala donacioides Reeve 1857: Macpherson & Chapple, 1951. *Mem. Nat. Mus. Vict.*, Vol. 17, p. 153.

This species, previously known from Victoria and South Australia, has been found to be common at Sandy Bay, particularly at Nutgrove Beach and Derwentwater Beach (also known as Wrest Point Beach). Live specimens are sometimes washed ashore.

Localities:

(i) Sandy Bay, near Hobart, Derwent Estuary, Tas. Various dates from 26th January, 1963. (T.M. Collection).

(ii) Coles Bay, Freycinet Peninsula, E. Tasmania. A single specimen collected by R. C. Robertson, 23rd October, 1963. (T.M. E3848).

Remarks:

Specimens from this area show some variation in colouring. Some are purple, as described by Macpherson & Gabriel (1962) for Victorian specimens, but others are predominantly cream, both internally and externally, with varying amounts of purple. The epidermis also varies from the typical semi-transparent horn colour, some specimens having the epidermis thick and blackened towards the edges, while in others it is reddish-brown.

The largest specimen collected measures 44 mm. x 24 mm.

ACKNOWLEDGMENTS

My thanks are due to Miss J. Hope Macpherson National Museum of Victoria, for advice and help with identification and to Mr. Ralph Robertson, of Hobart (formerly of Cygnet), who supplied information about Maoricolpus roseus included in this paper, and who has also generously provided me with many specimens. I am also grateful to Misses Joyce Howard and Elizabeth Aves, and to Rev. P. Noonan and Mr. J. Farnell, who have all supplied information and specimens which are included in the Tasmanian Museum collection.

ADDENDUM

Since this paper went to press, another New Zealand species which is established in southern Tasmania has been found.

Family: NUCULANIDAE.

Neilo australis (Quoy & Gaimard 1835)

Nucula australis Q. & G. 1835, Voy. Astrolabe (iii), p. 471, pl. 78, f. 5-10.

Neilo cumingii A. Adams 1852 (1854), *Proc. Zool. Soc. Lond.*, p. 93.

Ctenoconcha navicula Valenciennes, Voy. "Venus", Moll., pl. 23, f. 7.

Neilo australis (Q. & G.); Smith, 1874, "Ereb. & Ter.", p. 6, pl. 2, f. 13.

Solenella australis (Q. & G.); Hutton 1884, Proc. Linn. Soc. N.S.W. (ix), p. 529.

Malletia australis (Q. & G.); Suter 1913, Man. N.Z. Moll., p. 837, pl. 58.

Locality: Derwent Estuary at Hobart, 29th March, 1965. (Nos. E3991-3993).

A series of bottom grabs was made across the Derwent Estuary from Howrah to Long Point, Sandy Bay. Living and dead specimens were obtained from the mud bottom, from depths of 20 to 80 feet. The only other live molluscs taken in the grab were a few specimens of Scaeoleda crassa (Hinds 1843). Numerous dead specimens of N. australis were also obtained from a single haul with a dredge off Long Point, in about 20 feet.

Remarks:

The habitat is similar to that given by Powell (1961, pl. 10) for New Zealand specimens—"deep water, mud bottom". However, as Powell (1961) and Suter (1913) both describe the species as rare or very rare, it is surprising that in the section of the Derwent Estuary investigated Neilo australis was present in large numbers. The largest shell collected was 32.7 mm. x 17.0 mm. This is smaller than the type, which is 36 mm. x 18 mm. (Suter, op. cit.) Local specimens agree with Suter's description.

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Plate.

Fig. 1.—Maoricolpus roseus (Q. & G.).

Fig. 2.—Paphirus largillierti (Phil.).

Fig. 3.—Paphirus largillierti (Phil.). Young specimen. 27.4 mm. x 21.0 mm.

Fig. 4.—Soletellina donacioides, Reeve 1857.

IV. VEGETATION: ADDITIONS AND CHANGES—THE FISHER ISLAND FIELD STATION

By

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(With 1 plate and 1 text figure)

INTRODUCTION

Fisher Island lies in Franklin Sound between Flinders and Cape Barren Islands in Eastern Bass Strait and has attained fame as the focal point of the C.S.I.R.O. investigation into the mutton bird (*Puffinus tenuirostris*) begun in 1947 under the leadership of Dr. D. L. Serventy.

A general account of the island appeared in this journal in February 1958 (Guiler, Serventy and Willis) but further facts have come to light regarding the vegetation and it seems appropriate to record these for use by subsequent workers at the field station.

Thanks to the generosity of the C.S.I.R.O. Wildlife Survey Section, the author was able to spend a large part of three summers (1958-1960) at the research hut. Mr. J. H. Willis, Assistant Government Botanist at the National Herbarium of Victoria, who is responsible for the only other published information on the Fisher Island flora, was able to spend only a few days on the island. Unfortunately his stay, in April 1954, coincided with the end of a long dry summer when the plant life was at its sparsest. Adding his records to those of plants sent to him from the island by C.S.I.R.O. personnel in 1948, 1949 and 1952, he was able to list 47 species—33 natives and 14 aliens. The 1958 to 1960 seasons yielded a further 48 species—23 natives and 25 aliens—and the author is indebted to Mr. Willis and his staff for checking the identifications of these.

The 95 species recorded up to March 1960 are listed below.

Table 1

SPECIES RECORDED ON FISHER ISLAND UP TO MARCH, 1960

x = alien sp.; H = in Fisher I. herbarium; M = Fisher I. plant identified at Melbourne herbarium; m = specimen from another Bass Strait I. identified at Melbourne herbarium; W = recorded by Willis, 1958. (z) = having xeromorphic features.

	H m	Posidonia australis
	HM	Zostera tasmanica
	HM	Zostera muelleri
	HM	Cymodocea antarctica
	H	Halophila ovalis
	xHM W	Dactylis glomerata
	xHM W	Vulpia bromoides
	xHM W	Bromus mollis
	xHM	Bromus diandrus
	xHM W	Briza maxima
	xHM	Briza minor
(z)	HM W	Poa poiformis
	H mW	Deyeuxia quadriseta
	HM W	Dichelachne crinita
	H m	Agrostis avenacea
(z)	H mW	Stipa teretifolia
	xH mW	Holcus lanatus
	xH mW	Aira caryophyllea
	xHM	Avena strigosa
	xH mW	Avena sativa
	xH m	Lolium perenne
(z)	H mW	Parapholis incurva
(z)	M	Monerma cylindrica
	HM	Isolepis platycarpus
	HM	Isolepsis cernuus
	HM	Centrolepsis strigosa
	HM	Juncus bufonius
(z)	H mW	Juncus pallidus
(z)	H mW	Dianella revoluta
(z)	H mW	Bulbine semibarbata
	HM W	Microtis unifolia
	HM W	Muehlenbeckia adpressa
	xH m	Atriplex hastata
(z)	HM W	Rhagodia baccata
(z)	H m	Suaeda maritima
(z)	HM W	Salicornia australis
(z)	HM W	Arthrocnemum arbusculum
(z)	HM	Hemichroa pentandra
(z)	H mW	Disphyma australe
(z)	H mW	Carpobrotus rossii
(z)	H mW	Tetragonia implexicoma
(z)	HM W	Calandrinia calyptrata
	xH m	Stellaria media
	HM	Stellaria multiflora
	xHM	Cerastium glomeratum
	xHM	Moenchia erecta
	xHM	Sagina apetela
(z)	HM W	Spergularia media
	HM	Polycarpon tetraphyllum
	xHMm	Tunica prolifera
	xH m	Silene gallica
	x W	Silene anglica
(z)	H mW	Clematis microphylla
(z)	H mW	Lepidium foliosum
	xHM	Hymenolobus procumbens
(z)-	HM W	Crassula sieberiana

HM	Acaena anserinifolia
(z) H mW	Acacia longifolia v. sophorae
(z) H mW	Acacia mucronata?
x M	Trifolium campestre
xHM W	Trifolium dubium
xHM	Trifolium cernuum
x m	Trifolium fragiferum
xHM	Trifolium glomeratum
xHM	Trifolium subterraneum
xHM	Trifolium arvense
xHM	Trigonella ornithopodioides
xH m	Medicago sativa
xHM W	Melilotus indica
H mW	Pelargonium australe
xHM	Geranium molle
H mW	Oxalis corniculata
x M	Lavatera arborea
HM	Daucus glochidiatus
(z) H mW	Apium prostratum
(z) H mW	Leucopogon parviflorus
xH m	Anagallis arvensis
H m	Centaurium pulchellum
(z) H m	Alyxia buxifolia
xHM	Plantago coronopus
(z)xHM W	Coprosma repens
(z) H mW	Stylidium graminifolium
H mW	Lagenophora stipitata
H mW	Brachycome diversifolium v. maritimum
(z) HM W	Olearia stellulata
(z) H mW	Helichrysum bracteatum v. albidum
(z) H m	Gnaphalium luteo-album
HM	Cotula vulgaris v. australasica
(z) HMm	Cotula coronopifolia
mW	Senecio linearifolius
HMmW	Senecio glomeratus
xHM W	Hypochoeris radicata
xHM	Hypochoeris glabra
xHM	Sonchus oleraceus
xH mW	Sonchus asper

56 native spp. 39 introduced spp. = 41%

FLORISTIC COMPONENTS

31 families are represented in the above list, 5 of them by aliens only, viz. Papilionaceae (10 species), Malvaceae, Primulaceae, Plantaginaceae and Rubiaceae. (*Hemichroa* has been placed in the Chenopodiaceae, not the Amaranthaceae). Analysis of the 7 families best represented is included below.

Components of the 7 Best Represented Families.

Family	Number of species		
	Native	Introduced	Total
Gramineae	7	11	18
Compositae	9	4	13
Caryophyllaceae	3	7	10
Papilionaceae	0	10	10
Chenopodiaceae	5	1	6
Potamogetonaceae	4	0	4
Aizoaceae	3	0	3

7 further families are represented by 2 species each and 17 families by 1 species.

Deyeuxia, Stylidium and *Lagenophora* have not been recorded since 1954, *Lavatera* not since 1958.

This vegetation differs fundamentally from that of Flinders and Cape Barren Islands in that it lacks almost all the woody sclerophylls which dominate the larger islands. These woody families, principally Myrtaceae, Proteaceae, Epacridaceae and Mimosaceae, are represented on Fisher Island only by the localised *Leucopogon parviflorus* and *Acacia longifolia* var. *sophorae*.

Exposure to wind and spray undoubtedly contributes to the paucity of shrubs, as pointed out by Willis, but the poor shallow soils which he cites are probably not so important. On adjacent islands it is these very soils, situated on granite outcrops, which support the major shrub growth, the deeper soils between having been denuded of woody plants partly by the big population of burrowing birds and partly by the periodic burning which is practised.

Most of the Fisher Island species occur as components of the impoverished coastal flora of the larger islands but *Lepidium foliosum* was found only on the smaller islets and reefs. Although no doubt once more widespread, this cress does best in the absence of grazing mammals and the presence of defaecating seabirds.

The Fisher Island species list is a great deal longer than that for any other island of equivalent size (2.1 acres) and exposure visited in the Furneaux Group. This is mainly accounted for by the high incidence of aliens crossing from the nearby crayfish and mutton bird port of Lady Barron on Flinders Island, the frequent traffic of scientists to and from the 'Island Stores' and the landing of loads of firewood, the only cooking fuel.

SOIL FACTORS

The Devonian granite weathers to give an acid, siliceous sand, the pH of 12 samples taken from various parts of the island averaging 4.75 and ranging from 4.0 to 7.0, with only 1 sample, a coastal one, approaching neutral. This pH does not differ significantly from that of the commercial mutton bird islands, but the proportion of organic matter in the Fisher Island soil is very much larger than on these. Soil ignited in a tin on the cooking fire loses more than half its volume and the average weight loss on ignition for 2 hours at 900°C of 12 samples previously dried to 105°C by Mr. J. T. Hutton of the C.S.I.R.O. Division of Soils, Adelaide, was 28%. Figures ranged from 18% to 45% and represent the organic matter content fairly accurately as the mineral matter content of the samples was mostly coarse sand.

23 samples from the adjacent Little Green Island, which is regularly fired by the birders, averaged exactly half that of the Fisher Island soils (14%), while 17 samples from Great Dog Island (also regularly burned) averaged only 9.4% of organic matter. The unburned islet of Inner Possum Reef, on the other hand, showed an average of 36% of organic matter (15 samples). The organic carbon figure for these samples is about 56% of the recorded loss on ignition.

A higher organic content in these sandy soils implies a higher water holding capacity, the average percentage moisture content for air-dry Fisher Island and Possum Reef samples being 5.2% and 6.6% respectively, that for Little Green and Great Dog Islands being 1.8% and 1.5%. Nevertheless, the thin skins of peat overlying much of the rock on Fisher Island dry out in summer until they become almost un-wettable. The greatest difficulty was experienced in watering even pulverised samples of this humic material in which seed viability experiments were being carried out, the water rolling off the surface in globules. Such soils are likely to remain sodden for longer than the native sands in winter but would be unable to absorb the light summer showers which can prolong plant growth into an unfavourably dry season. Many of the species which they support are winter annuals, even the succulent-leaved *Calandrinia calyptrata* and *Crassula sieberiana* dying off as the summer advances.

Typical species of the shallow peats overlying inland rocks are *Centrolepis strigosa, Juncus bufonius, Stellaria multiflora, Cerastium glomeratum* and *Moenchae erecta.* The most typical species of the coastal peat fringe which encroaches onto the granite shoreline is *Cotula vulgaris* var. *australasica* which forms a narrow zone below the marginal belt of *Disphyma australe.* The latter, with *Carpobrotus rossii* and *Hemichroa pentandra,* with which it shares these thin peat crusts, are creepers, tapping a wider range of soils than the annuals and often rooted in deep crevices.

Deeper soils with a higher sand content are burrowed by shearwaters, which ensure a more adequate mixing of the organic and mineral fractions than when the surface deposites remain undisturbed.

Table 3 shows the characteristics of 12 soils from various parts of Fisher Island.

Table 2

SOME CHARACTERISTICS OF SOIL FROM TWELVE SAMPLES COLLECTED ON FISHER ISLAND

No.	Part of Island	Depth of Sample (inches)	Soil Colour	Undecayed Plant Material	Loss on Ignition	Organic Carbon	Moisture in the Field	Moisture in air-dry Soil	pH	Rookery	Dominant vegetation of the immediate Sample Area
					%	%		%	%		
1.	South ..	2	Black	Small	25	..	Wet	5.9	7.0	Snake Gully	*Tetragonia, Apium, Poa* and *Disphyma*
2.	South ..	10	L. Brown	Large	33	..	V. Wet	7.3	4.5		
3.	Centre ..	2	D. Brown	Medium	32	..	Dry	5.6	4.0	South	*Dactylis, Avena, Dianella* and *Bromus*
4.	Centre ..	10	Black	Small	19	..	Damp	3.9	4.0		
5.	East ..	2	Brown	Large	40	21	Dry	6.3	4.0	Potts Point	*Poa, Briza* and *Coprosma*
6.	East ..	10	Brown	Large	45	..	Dry	7.4	4.5		
7.	North ..	2	Brown	Large	24	..	Dry	3.7	4.5	Home	*Poa and Bromus*
8.	North ..	10	Brown	Large	18	..	Damp	3.0	4.0		
9.	Southwest ..	2	Black	Small	40	..	Wet	7.9	4.5	None	*Disphyma*
10.	Northeast ..	2	Black	Small	36	20	Wet	7.8	6.0	None	*Cotula*
11.	North ..	2	Black	Large	22	..	Damp	3.6	4.0	Home	*Poa*
12.	Centre ..	2	Black	Large	39	22	Damp	8.1	6.0	None	*Poa*
	AVERAGES ..	..	..	..	28	..	..	5.2	4.75	..	..

Loss on ignition is equivalent to content of organic matter (% by wt.). Organic carbon is equivalent to 56% of total organic matter.

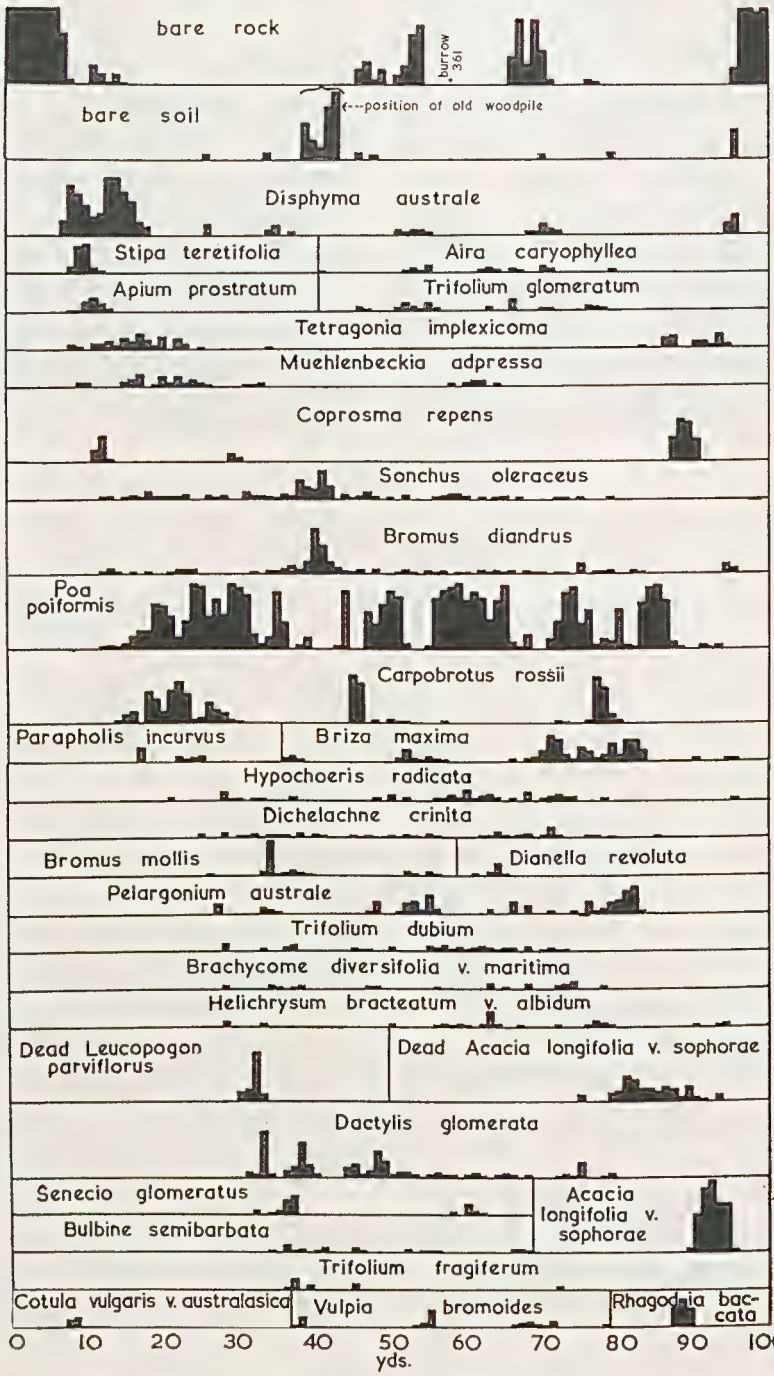
SUMMER DROUGHT

With so many mesophytic annuals in the flora, summer drought can be a limiting factor to a high proportion of the Fisher Island plants. Although the average annual rainfall is about 30 inches (760 mm.) per annum, or approximately the same as on Skokholm Island in West Wales (Goodman & Gillham, 1954), little of this falls in the summer months (December to February) (Serventy, 1958). The Southern Hemisphere Island (Lat 40°S) experiences a higher evaporation rate than the Northern Hemisphere one (Lat. 52° N) and the ratio of xerophytes to mesophytes among the perennial plants is consequently higher.

Willis, 1958, remarks that almost all the plants present on Fisher Island in April 1954 possessed xeromorphic characters, but this is only true of those species perennating above ground during the summer. Only 32 species, or a third of the total, are xeromorphs and these are prefixed with (z) in the accompanying species list. 5 other species are marine and submerged by all tides and a few are aestivating geophytes, but most of the non-xeromorphs are ephemerals, accomplishing one or more generations during the moister conditions of autumn, winter and spring. (There is neither frost nor snow to check winter growth.) The most numerous groups in this category are in three of the four best represented families, viz the grasses, clovers and Caryophyllaceous ' weeds '.

As in the 1954 drought, most of these species disappeared during the unusually dry summers of 1959 and 1960. (Shade temperatures rose to 101°F (38.3°C) in January 1960.) Even the most succulent and sclerophyllous plants suffered severe wilting during this period and a high proportion of the withered *Coprosma* leaves, normally evergreen, were exfoliated. The 3 Aizoaceous species recovered turgidity apparently by the absorption of dew or atmospheric moisture as only one fall of rain, of considerably less than 1 inch (25 mm.) occurred during the subsequent 2 months and this was scarcely sufficient to wet the parched soil. All 3 species bore a high proportion of small reddish drought-resistant leaves. *Bulbine semibarbata, Lepidium foliosum* and other perennials remained dwarf, *Poa poiformis* and *Stipa teretifolia* shoots were dry and brittle and few annuals survived the prolonged heatwave.

FISHER ISLAND VEGETATION IN RELATION TO EXPOSURE
Belt transect (100 X 1 yd.) from H.W.M. on W. to H.W.M. on E.
percentage cover histogram. 24. 1. 58.



EXPOSURE TO WIND AND SEA SPRAY

a. *Land Flora*

The accompanying histogram shows the percentage ground cover of plant species along a 100 yd. (92.3m.) belt transect running from the exposed western coast of the island to the sheltered eastern coast. The overall zonation is from succulent *Disphyma australe* through the main central zone of *Poa poiformis* tussock to *Acacia longifolia* var. *sophorae* scrub. The more salient features of the zonation revealed by the transect can be summed up as follows:

The most seaward *Disphyma* mingles with the coastal fringe of *Cotula vulgaris* var. *australasica* and is superceded on the inland side by a belt of *Stipa teretifolia*. This coastal tussock grass borders the more exposed west and south sides of the island, withstanding slightly less sea salt than *Disphyma*, athough more maritime in its distribution in that it does not reappear on inand rocks.

The next belt is of mixed *Apium prostratum* and *Coprosma repens*, followed by a broader zone of *Tetragonia implexicoma* which merges into a similarly broad zone of *Carpobrotus rossii* with a little *Parapholis incurva* and *Muehlenbeckia adpressa*. The last, like *M. complexa* in New Zealand (Gillham, 1960), is typically associated with *Poa* tussock in areas subjected to considerable wind but not too much salt spray. The mesophytic leaves suffer readily from salt scorch and woody galls, each housing from 1 to 3 grubs ½-1" long, occur on the creeping woody stems.

Poa poiformis, the island dominant, begins to appear at the inner margin of the *Stipa* zone, increasing to a fairly overall cover beyond the more essentially coastal plants cited above. On inland rock outcrops it gives way to *Disphyma* and *Carpobrotus* associated with less halophytic saxicoles, principally *Bulbine semibarbata*, *Pelargonium australe* and *Brachycome diversifolia* var. *maritima*. Smaller subordinates featuring less conspicuously in the transect are the winter ephemerals of the peat crusts.

Shrubs other than *Coprosma repens* appear only towards the east end of the transect. The alien *Coprosma* from New Zealand appears by its distribution on all the islands to be more exposure resistant than any of the native shrubs. With *Rhagodia baccata* semi-shrubs it protects the windward side of the *Acacia longifolia* var. *sophorae* clump which appears in the transect and is, nevertheless, dead or severely wind-scorched except on its leeward fringe. *Rhagodia*, although a succulent-leaved Chenopodiaceous halophyte, shuns the most exposed situations and grows much less tall than the sheltering *Coprosma*. Below the eastern *Acacia* scrub the granite drops away to a wave cut platform in a more or less vertical cliff and the coastal belts are telescoped, *Carpobrotus* and *Tetragonia* leading down to *Disphyma* and sparse *Spergularia media*.

b. *Marine flora*

The fetch is greater to the south of Fisher Island than to the west (Guiler, 1958), so wave action is likely to be most intense on the south coast. It is never great, however, and, although brown algae predominate in the south and west, these do not include the larger surf lovers. Some, such as *D'Urvillea antarctica* and *Macrocystis pyrifera*, wash ashore, presumably from regions outside Franklin Sound, but the main species found attached are members of the Fucales. *Hormosira banksii* forms a continuous belt around the island but species of *Cystophora*, *Cystoseira*, *Sargassum* and *Scaberia* are more localised. Passing eastward, particularly along the land facing north coast, large members of the Siphonales become conspicuous, among them *Caulerpa cactoides*, *C. simpliuscula*, *C. sedoides* and *Codium muelleri*.

Fine growths of marine angiosperms cover the silty sea bed off the north and north east shores. *Posidonia australis* is dominant, bordered on its upper fringe by the smaller *Zostera tasmanica* and *Z. muelleri*. A little *Cymodocea antarctica* occurs in lower parts of the *Posidonia* 'meadows', which are uncovered only by low springs. (Tidal range around Fisher Island is only just under 6 ft. (2 m.), 2 ft. more at springs and 2 ft. less at neaps.). *Halophila ovalis* grows sparsely among the other Monocotyledons but is more often found in driftweed.

After heavy weather on February 1st 1960 considerable quantities of *Posidonia* fruits, open capsules and winged seeds were washed up into crevices. This phenomenon had not been observed before on Flinders Island by local naturalists, nor in the Eastern States by Mr. J. H. Willis, but is apparently not uncommon in Western Australia. 3 weeks later, on 20th February, 1960, many of the seeds were seen to have germinated in the shallows around the east and south east coasts. The average shoot length at this time was 1-2 inches 2-5 cm.) but some were longer and showed incipient rhizome formation where the juvenile leaves had died away. Internodes were short and the earliest formed leaves bore only rudimentary laminae, the leaf sheaths terminating in auricular like outgrowths. Many seedlings had been washed from their roothold and it was obvious that there was considerable wastage at this stage—provided for by the prolific, though irregular, seed production.

VEGETATION CHANGES DURING THE 1950's.

During the 8 years after the vegetation was mapped by Mr. G. M. Storr in 1952 *Acacia*, *Leucopogon* and *Carpobrotus* decreased and *Olearia*, *Rhagodia*, *Tetragonia*, *Coprosma*, *Stipa* and exotic grasses increased, though much of the *Rhagodia* subsequently died back.

Willis, 1958, comments that both *Acacia* and *Leucopogon* had been dying back, with minor recuperations, since 1950. He estimated that the *Acacia* covered 350 sq. yd. or 3.3% of the island's area in 1954, but the area was much less in 1960. The 1958 transect shows a width of only 2 yd. (less than 2 m.) at the east margin of the *Acacia* thicket to consist of still living bushes. A further 5 yd. (4½ m.) strip showed incipient die back and completely dead bushes occupied a belt 14 yd. (12½ m.) wide to windward of this. No regeneration was noticeable. The phyllodes of otherwise healthy plants were badly infested by black and white scale insects during the early part of 1960.

Leucopogon parviflorus in 1954 formed scattered clumps up to 10 yd. (c. 9 m.) across in the centre, south east and south west of the island. By 1958 all these bushes were dead but a small clump had grown up on North Point and been subsequently killed back to leave few living shoots. By 1960 this too had died out, but a number of saplings about 1 ft. (30 cm.) high were found scattered throughout the island. As existing plants have not been seen to set seed, it is likely that this regeneration was from succulent fruits brought from other islands by gulls. The life expectancy of individual *Leucopogon* bushes on Fisher Island seems to be short at present. That this has not always been the case is shown by the existance of old trunks of both this species and *Acacia*, of vastly greater girth than anything living today.

Shrubs as a group occupied less ground in 1960 than in 1952 but there had been a pectacular increase in the amount of *Coprosma repens*. This species does not figure at all on the detailed 1952 map but was much the most widespread and tallest shrub on the island in 1960, reaching commonly to 5-6 ft. (1.5-1.8 m.) in height. It showed ready establishment in rock crevices on the north west corner, but plants remained dwarf and wind trimmed there, often only the leeward one of the 4 rows of leaves and shoots remaining alive.

Although most of the larger *Olearia stellulata* bushes showed die-back, a number of young ones were becoming established in the north, east and south. *Rhagodia baccata* also showed cyclic change, dying in some areas, particularly in the south and south east, and regenerating in others.

It is evident that degeneration and regeneration of shrubs proceed side by side, but there appears to have been an overall retrogression over the past ten years, with only part of the damage made good. Over a period this would account for the smaller maximum size of existing shrubs as well as the smaller ground coverage.

Similar fluctuations occur among herbaceous species but damage to these is more readily repaired and long term changes are less pronounced. Willis mentions dying back of *Disphyma, Carpobrotus* and *Tetragonia* in 1954, but recovery of these may be effected within a few months in suitable weather—as shown by plants on Reef Island, just offshore after the entire vegetation there had been browned by a salt storm. These 3, *Coprosma* and others all suffered considerable drought damage in January 1960 but had more or less recovered 2 months later, in spite of negligible rainfall.

The progressive succession of plants where soil and shelter are adequate is from succulents to tussock grass and so to shrubs, but in 1960 there was more evidence of retrogressive succession, *Poa* tussocks growing up through the disintegrating shrubs and being overrun themselves in places by *Disphyma* or *Tetragonia*.

VEGETATION OF SHEARWATER ROOKERIES

It seems that the burrowing birds may be playing a significant role in producing long term changes in the Fisher Island plant communities and short term changes in the immediate vicinity of burrows. Floristic analyses were made in the 3 mutton bird rookeries and table 4 summarises their main points. The 251 m. valence squares in each community were random except in so far as each incuded a burrow entrance. In the Home Rookery, where burrows were closest, 9 of the squares contained more than a single entrance.

The persistence of a certain amount of woody vegetation and the relative sparsity of burrows in the Potts Point Rookery of the east suggests that this may be less old established than the other 2 but there is no historical evidence for this belief. The birds certainly appear to have had less influence on the vegetation here than elsewhere, one contributory reason being that the effect of their soil disturbance and guano deposition is less aggravated here by abrasive winds and salt spray deposition.

The Home Rookery of the north is heavily populated by birds whereas the area analysed west of South Rookery and Snake Gully (see Serventy, 1958) is a colony that has passd its zenith and the scars left by the bird are in process of healing.

77% of the burrows in the 25 valence squares analysed in the newer(?) Potts Point Rookery (I) were habitable, 63% in the well established Home Rookery (II) and only 32% in the degraded South West Rookery (III). The remainder had collapsed or were overgrown. Bare soil was greatest in II and least in III, facilitating the entry of a sparse covering of many 'weed' species between the *Poa* tussocks of II. 59% of these colonists were aliens, this number dropping to 38% in III where much of the bare soil at burrow entrances had been overgrown by more permanent vegetation. The percentage of annuals dropped similarly, from 47% in II to 31% in III.

Table 3.

Floristic Analysis of Three Types of Shearwater Rookery.

Locality:	I. Potts Point Rookery	II. Home Rookery	III. W. of main South Rookery
Type of rookery:	Fairly sparsely burrowed	Heavily burrowed	Degenerate; many burrows overgrown
% of occupied burrows:	77%	63%	32%
% of collapsed and/or overgrown burrows:	23%	37%	68%
% of bare ground in 25 valence squares (random, but each containing at least 1 burrow):	16.5%	52%	7.5%
Shrubs:	Some persisting in community but only dead twigs in valence squares.	None	None
No. of species in 15 valence squares:	12	17	13
% of aliens:	58%	59%	38%
% of natives:	42%	41%	62%
% of succulents:	12.5%	18%	35%
% of annuals:	42%	47%	31%
% of perennials:	58%	53%	69%
% ground cover of Poa poiformis:	68%	34%	31%
% ground cover of Tetragonia implexicoma:	7%	5%	50%

Poa poiformis dominated rookeries I and II, occupying twice as much ground in I where there was less bird excavation and no tussock cutting by man as in II. *Tetragonia implexicoma* dominated rookery III, having occupied most of the previously bared soil and grown over both *Poa* and burrow entrances. Some of the existing nest holes were roofed solely by the *Tetragonia* mat and the soil of the whole area was shallow, resembling a rookery which has degenerated due to loss of soil where erosion has followed trampling or burning. This is the most windswept corner of the island where erosion might have occurred when there was much soil bared at the burrow entrances before the *Tetragonia* gave protection. The only other modifying factor is likely to be trampling by humans. Whatever the cause of the degeneration, it illustrates the instability of rookeries on shallow soil and emphasises the danger of worsening conditions in such rookeries by fire or any other practice which exposes bare ground.

In 1958-60 the *Tetragonia* gave stability and made possible the persistence of burrows in soil only a few inches deep. It has, nevertheless, been suggested (Serventy, 1958) that the *Tetragonia* mat hinders and possibly prevents burrowing. This seems unlikely, in view of the fact that the interweaving stems of the 'bower spinach' seldom constitute so formidable a barrier to peneration as the close-knit stools of the grass tussocks, which hinder the birds not at all. On loose sandy soil the 'spinach', like bracken, can be of undoubted benefit as a stabiliser, but it may, like bracken, have more subtle effects in deterring the birds where this stabilising property is of no advantage.

Many of the numbered pegs indicating previously occupied burrows in the degenerating South West Rookery could not be related even to an overgrown hollow in 1960, showing where a burrow might once have existed.

Some chicks in the Potts Point Rookery were seen on the ground surface beneath 'bowers' of *Tetragonia*. Dead *Acacia* stems formed a framework for these bowers, which had grown over the *Poa* tussocks following after the *Acacia* in the degenerative plant succession. This is a small scale version of the general sequence for shearwater colonies, viz.

Phase 1. Scrub (in this case *Acacia* with *Rhagodia* and *Olearia*) burrowed by shearwater whose dung initiates their death and allows the shorter *Poa* to compete adequately. It is a late stage of this phase which occurs in the Potts Point Rookery.

Phase 2. Supremacy of *Poa* tussock with considerable bare soil on which casuals, particularly *Sonchus oleraceus*, can become established but none of which become common. e.g. the Home Rookery.

Phase 3. Degeneration of the *Poa* possibly due to senility, possibly hastened by bird disturbance and erosion and followed by overrunning with guano-loving *Tetragonia*. On the west margin of the Home Rookery this, like *Disphyma*, is able to overgrow healthy tussocks, but it naturally competes better where the *Poa* is degenerating. e.g. the South West Rookery where the *Poa* is inhibited to some extent by blown sea spray.

In the Home Rookery 22 occupied burrows showed an average ground cover of 3.2% *Tetragonia* whereas 13 disused burrows showed a 7% cover. (These figures represent the percentage cover in the 1 m. valence squares, not in the burrow entrances alone).

The nest site of the sooty oyster catchers (*Haematopus unicolor*) is another small scale example of the overrunning of *Poa* by a succulent creeper in a bird disturbed habitat. 1958 photographs of the nest show upstanding *Poa* on its seaward side. By 1960 this was dead and the prostrate shoots covered over by *Disphyma*.

OLD GULL COLONIES

In the 1948-49 breeding season silver gulls (*Larus novae-hollandiae*) nested between the eastern *Acacia* scrub and the North East Boat Harbour (Serventy, pers. com.) *Poa* is still dominant here (or has resumed dominance) but the gulls may be responsible for the abundance of the succulent ornithocoprophile, *Bulbine semibarbata* and the alien annual, *Briza maxima*. *Bulbine* also becomes locally dominant just below the granite slab by the hut where food scraps are thrown for the gulls. Its associates here are the equally coprophilous *Disphyma* and, in spring, alien grasses.

In the 1950-51 breeding season 15 gulls' nests were built west of the hut but no eggs were laid (Serventy, pers. com.). This area either coincides with or is very close to that in which *Coprosma repens* has been increasing in recent years. The influx of gulls was followed by an influx of the prickly fruited, animal dispersed *Acaena anserinifolia*, most of which has since been pulled out by hand to prevent further spread.

PLANT DISTRIBUTION BY GULLS AND STARLINGS

Apart from the *Acaena* referred to above, the species most obviously spread by birds (although originally introduced by Miss Liela Barrett) is *Coprosma*. The numerous small saplings which are becoming established in coastal crevices, particularly in the north west where gulls congregate to await the after-meal scraps from the hut, have presumably been brought by the birds. When feeding on the copious crop of orange two-seeded drupes in February, March and April, silver gulls usually hover just above the bushes, reaching downwards to take the clustered fruits several at a time, but are sometimes seen to alight on the twigs. In the summer of 1960 *Coprosma* seed pellets ejected from their crops were common throughout the island. One containing 40 seeds in a matrix of damaged skins was sown on peat in a seed box and tended for 7 weeks but showed only those signs of germination seen in newly expectorated seeds, viz. the hinged triangular flap at one end lifted or broken away to expose the embryo. *Coprosma* fruits are also eaten by a pet galah (*Kakatoë roseicapilla*).

Starlings (*Sturnus vulgaris*) are very fond of *Coprosma* fruits, dividing their attention between the older established bushes west of the hut and the largest of the newly established colonies which is superceding the *Acacia* in the east. Here they habitually congregate on the *Acacia* twigs, which form the nearest suitable perch to their nesting crevices in the east cliff beneath. Germination of the pairs of hard seeds defaecated onto the ground beneath is almost certainly responsible for the present growth of *Coprosma* saplings.

When feeding on the succulent red fruits of *Tetragonia*, silver gulls will settle on mounds of this species among fairly dense tussock where their view of approaching danger is unusually restricted. Crop pellets of *Tetragonia* seeds are common at certain seasons.

A small sapling of *Alyxia buxifolia*, another succulent fruited shrub, was recorded for the first time in 1960. It was in a northern area much frequented by gulls and where two recent invasions of the succulent fruited *Leucopogon parviflorus* had occurred, both species very likely brought by the gulls.

ACKNOWLEDGEMENTS

My grateful thanks go to the Wildlife Survey Section of the Commonwealth Scientific and Industrial Research Organisation for facilities on Fisher Island and to them and the Science and Industry Endowment Fund for their generous grants towards financing the work. Also to Dr. D. L. Serventy for much lively discussion and help in the field, Mr. J. T. Hutton for the analysis of soil samples and members of the Melbourne Herbarium for the identification of plant specimens.

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Plate 1.—Dead *Acacia longifolia* var. *sophorae* trunk, much larger than any of those now existing. The *Coprosma repens* sapling (probably planted by fruit-eating starlings perching on the *Acacia* above their nest crevices) shows exfoliation due to drought and salt scorch. East Fisher Island, Summer, 1960.

Plate 2.—*Arthrocnemum arbuscelum* grading downwards through *Suaeda maritima* to *Salicornia australis* in the island's only "salt marsh". Note drifted leaves of *Posidonia australis*. North East Fisher Island, Summer. 1960.

Plate 3.—Coastal zonation on exposed shore; upwards from *Disphyma australe* through *Stipa teretifolia* and *Coprosma repens* to *Poa poiformis*. West Fisher Island, Summer, 1960.

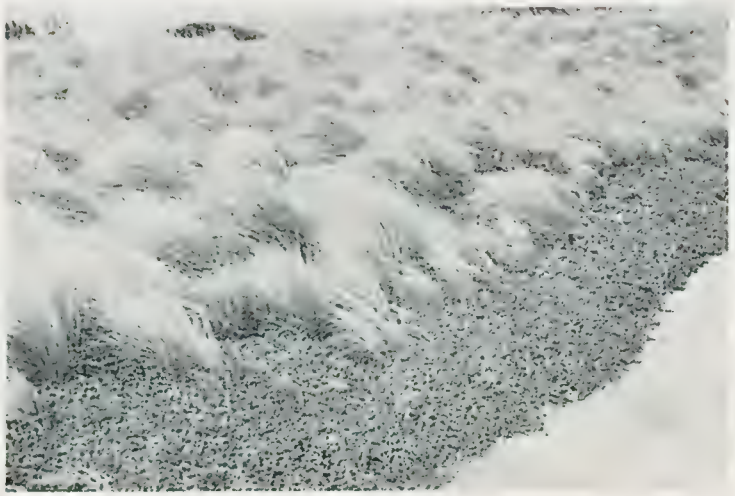

Plate 4.—Modified coastal zonation where the vegetation does not approach nearer than 18 m. to the sea. *Disphyma australe* bordering the windswept *Poa poiformis* which is the island's dominant plant. Stunted *Leucopogon parviflorus* in the distance, near North Point. North West Fisher Island, Summer, 1960.

Papers and Proceedings of the Royal Society of Tasmania, Volume 99.

NOTES ON SOME TASMANIAN AND AUSTRALIAN LEPIDOPTERA-RHOPALOCERA. II.

By

L. E. Couchman

(With one plate.)

These notes form a further contribution to a knowledge of the butterflies of this region. Some nomenclatural changes have been necessitated in connection with the preparation of a new book on the Australian butterflies, others are due to the discovery of new forms. The opportunity is taken to illustrate some hitherto unfigured species. Except where otherwise stated all types of new forms are in my own collection.

ABSTRACT

Hesperilla mastersi marakupa is described and figured, this is an unexpected addition to the list of Tasmanian butterflies; the food plant of *Oreisplanus munionga larana* Couchman is also recorded from this State. *Graphium macleayanus* ssp. *wilsoni* from the Atherton Tableland and ssp. *moggana* from western Tasmania are distinguished from the typical race from Port Jackson.

The subspecies of *Bindahara phocides* occurring in north-eastern Queensland which authors have placed as either *sugriva* Horsfield or *isabella* Felder is now designated ssp. *yurgama*. In continuation of the study of *Pseudalmenus chlorinda* Blanchard, the name *myrsilus* Doubleday and Hewitson is revived for the brilliant race from the Tasman Peninsula, and a remarkably melanic population in the Conara area is separated as ssp. *conara*.

The hitherto unknown female of *Heteronympha penelope panope* Waterhouse from the Cradle Mt. district is described.

HESPERIIDAE

Hesperilla Mastersi Marakupa subsp. nov.

Female: differs from *m. mastersi* from the Sydney area in that the subapical and discal hyaline spots of the forewing above are clearly separated by the dark brown veins, the subapicals narrow and elongated, the discal spots in areas 2 and 3 smaller and squarer in shape, conjoined discal spots in Ia, and an additional postbasal spot, 2 mm. in length.

Hindwing beneath, the brown ground colour more extensive than in ssp. *mastersi* Waterhouse, restricting all the light cream markings, particularly narrowing the light cream streaks at the end of cell in area 5. Forewing length 21 mm.

Holotype female labelled 1 mile S. of Bridport, Tasmania, Sea level, 13th December, 1963. R. Couchman.

This is a magnificent addition to the Tasmanian list, since *m. mastersi* has always been regarded as the finest and rarest species of the genus, found only in the coastal areas of New South Wales and north-eastern Victoria. There the larva has been found on *Gahnia melanocarpa* and *G. clarkei*, which plants are not recorded for Tasmania.
At Bridport on the edge of a swampy heathland area two or three small larvae were seen and a pupa taken from a distinctive larval shelter on *Gahnia* sp. (*radula*?), apparently a larger, more luxuriant plant than the *G. radula* of the Hobart district. The larval shelter was easily distinguished from the more numerous *Hesperilla donnysa aurantia* shelters on the same plant by the slight spiral twist of the leaves which formed the shelter; although not so strongly twisted it was reminiscent of the characteristic shelters of *Hesperilla chrysotricha plebeia*.

This species may perhaps be found through the heathlands of the north-eastern districts, but the original locality, as with so much of this area, has been cleared and placed under pasture, so that no further specimens have so far been found.

In the Tasmanian list *H. mastersi marakupa* Couchman should be placed before *H. chaostola leucophaea* Couchman. The subspecific name is the Tasmanian aboriginal word meaning handsome.

Oreisplanus Munionga Larana Couchman 1962.

At Marrawah in January, 1964, full-fed larvae and a few pupae of both sexes were found, head upwards, in shelters on a coarse tufted *Carex* sp. (*? appressa R.Br.*). Five males and one female emerged between 31st January and 8th February, so that the pupal duration in Tasmania is from 14-18 days.

Further efforts to trace the species in the extreme north-western areas away from the original locality at Marrawah have failed. To the south in the direction of the Arthur River the heathland seems not to harbour the *Carex* which has proved to be the larval foodplant, while to the north of Mount Cameron West the Van Diemen's Land Company refuses access to the entire area around Cape Grim, where possibly a small watercourse similar to that at Marrawah may provide a suitable habitat for foodplant and butterfly.

Clearing and grazing has undoubtedly brought this species to the verge of extinction in this State, it is still only known from the one small swamp of two or three acres in extent where it was originally found.

LYCAENIDAE

Bindahara Phocides Yurgama nom. nov.

Pro *Bindahara phocides isabella* Felder Waterhouse and Lyell 1914 (nec Felder 1860).

Sithon isabella Felder, Semper, G. 1879 Journal Mus. Godeffroy 5 (14): 167, 191; *Bindahara isabella* Felder, Waterhouse, G. A. and R. E. Turner, 1905, Proc. Linn. Soc. N.S.W. (1904) 29 (4): 804; *Bindahara phocides isabella* Felder, Waterhouse, G. A. and G. Lyell, 1914, Butterflies of Australia: 133-134. 20, f. 440, 441; Seitz, A., 1926, The Macrolepidoptera of the World, 9: 995, (nec. pl. 158h); Waterhouse, G. A., 1932, What Butterfly is that? 196. XXVI, f. 19, 19A.

Bindahara sugriva Horsfield, Miskin, W. H., 1891, Ann. Queensland Mus. I: 69; Waterhouse, G. A., 1903, Proc. Linn. Soc. N.S.W., 28 (1): 267-268. 2, f. 35, 36; id 1903 Mem. N.S.W. Naturalists' Club 1: 31. (nec Horsfield 1829, Java).

Male above when compared with ssp. *phocides* Fabricius has the brilliant blue marginal area of hindwing larger and semicircular in shape, extending from veins 3 to 7, 5.5 mm. in width in area 5. Beneath, forewing and costal area of hindwing grey pinkish-brown, median and discal bands dark brown; hindwing ground colour light fawn, a single large distinct subcostal spot in basal area dark brown, discal streaks faintly outlined brown, tail ochreous, 13 mm. long. The holotype male and allotype female will be the specimens in the Australian Museum Coll. as illustrated by Waterhouse and Lyell (1914), the male from Cape York taken in May, the female from Atherton taken in March. Paratype males from Atherton, N. Queensland. February 1944. F. Angel, in my collection.

This species, first recorded from Australia by Semper under the name of the Javanese subspecies, latterly has passed under *isabella* Felder, described from Amboina. G. A. Waterhouse recognised its distinctiveness in his last letter to me in 1941, but did not live to describe it. The name I have adopted is the north Queensland aboriginal word for quick, which well describes its flight.

Pseudalmenus Chlorinda (Blanchard) [1848]

This species proves to be very variable in Tasmania, far more so than in its much more extensive range in the mainland States, so that populations separated by a comparatively few miles are easily identifiable by wide differences in markings.

The typical subspecies *chlorinda chlorinda* from the eastern shores of the Derwent River and adjacent areas in both sexes has the submarginal red band of the hindwing above restricted to areas 1a and 2, sharply tapering off to a point in areas 3-4.

On Tasman Peninsula occurs a population to which Doubleday ascribed the name *myrsilus* in 1847 but without description. This is a brilliant insect, particularly in the female, with wide orange discal band on the forewing and broad orange central patch often connected to the extended orange-red submarginal band of hindwing.

At an elevation in the northern midlands occurs the remarkable melanic race for which I propose the name ssp. *conara*, having the normal orange markings of the female upperside completely veiled by black scaling. Elsewhere on the north coast east of Port Sorell and around Bridport, with an isolated population near Upper Scamander, the form is indistinguishable from the Victoria ssp. *zephyrus* Waterhouse and Lyell. This is a unique distributional pattern within an island as limited in size as Tasmania.

Pseudalmenus Chlorinda Myrsilus (Doubleday and Hewitson) [1851] n. comb.

Ialmenus myrsilus Doubleday, E, 1847 List of the Specimens of Lepidopterous Insects in the British Museum Pt. II: 28 (nom. nud.) "Van Diemen's Land". *Thecla myrsilus* Doubleday, E. and W. C. Hewitson [1851]. The Genera of diurnal Lepidoptera: pl. 75, f. 3. Westwood, J. O. [1852] ibid: 487, No. 138. "Van Diemen's Land".

It is also noted by Westwood on page X, List of the Plates, in the same work, but no description was ever given.

Edward Doubleday (1847) lists eight specimens in the British Museum, from Rev. A. Beaufort and Mr. Children, without any description, so as a valid name *myrsilus* must date from Hewitson's figure of the female upperside.

As I noted in 1962, in an area south of Orford the specimens of *Pseudalmenus* were larger even than the Victorian ssp. *zephyrus* Waterhouse and Lyell, in fact many were very close to the N.S.W. ssp. *chloris* Waterhouse and Lyell in size, brilliance of markings on the upperside and in the white ground colour of the underside. Concentrated deliberate burning of the Rheban area exterminated the larval food-plant, *Acacia dealbata*, and the host tree, *Eucalyptus viminalis*, which harboured the colonies of the ant, *Iridomyrmex foetans*, among which the larvae of the butterfly pupated. In the search for other localities my friend, A. M. Hewer, whose enthusiastic quest for this butterfly has added so much to our knowledge of its distribution, discovered pupae on the Tasman Peninsula near Saltwater River, and I have bred specimens from pupae each year since. It was immediately noticed that the females closely resembled Hewitson's figure of *myrsilus*, but it was not until a series of specimens had been bred over several years, agreeing well with the figure, that I became convinced that this name, which I and others had relegated into the synonymy of *Ps. chlorinda* Blanchard, should correctly be applied to the population isolated on Tasman Peninsula. The figure in the "Genera" shows a female specimen with the forewing possessing a broad orange discal band, towards the hindmargin slightly produced outwards along vein 1a, the black spot at end of cell clearly within the band; hindwing with a conspicuous central orange-red patch extending outwards for a small distance along the veins, an orange-red submarginal band rising broadly from tornus around hindmargin to area 6 where it terminates squarely.

The female specimen I figure is very close to Hewitson's plate, differing only in that the spot at end of cell is not quite as clearly surrounded by the discal orange band, otherwise it seems identical. The discal band of forewing is 5 mm. broad at costa narrowing slightly to 3.5 mm. at hindmargin; the submarginal band of hindwing 2.5 mm. broad at vein 2 and extending almost uniformly to vein 6. Beneath, the ground colour is whitish-grey, a sub-basal black streak along vein 1b, a large black spot at end of cell, a discal row of black spots 1 mm. wide at vein 1 tapering slightly to costa; hindwing with median row of narrow black spots from costa to vein 4, a uniform red submarginal band 1 mm. in width.

Female forewing length 16 mm.

The male neallotype of this subspecies differs markedly from *c. chlorinda* from the Richmond district.

Forewing above with discal orange band 3.5 mm. wide, clearly divided by black veins and surrounding a square black spot at end of cell; hindwing with a small central orange patch and broad orange-red sub-marginal band extending from tornus to vein 6.

Beneath, ground colour and markings as in the female.

Forewing length 14.5 mm.

The holotype is of course the female in the British Museum (Nat. Hist.) as figured by Hewitson.

Neallotype male labelled Plunkett Pt., Tas. c. 100 ft. 12 Nov. 1962. L. E. Couchman. Nine paratype males from this locality on various dates from 6th October to 19th November collected by A. M. Hewer, R. Couchman and L. E. Couchman, with them I associate five males from Lime Bay taken at sea-level by the same collectors. Females have been taken in both localities from 6th October through to 16th December.

The butterfly probably occurred in all suitable localities on Tasman Peninsula, but the founding of Port Arthur, with the subsequent burning, clearing and cultivation has now restricted it to a small coastal area near Saltwater River. The limits of this population are set by Norfolk, Frederick Henry and Storm Bays, effectively separating it from the nominotypical *c. chlorinda* around Richmond and the eastern shores of the Derwent River.

The activities on Tasman Peninsula from 1830 onwards in connection with the establishment of Port Arthur as a penal settlement, which in turn led to the use of the coal found near Saltwater River, would have afforded opportunities for collecting the specimens which Doubleday noted in the British Museum in 1847. The butterfly still to be found near the abandoned coal mines consistently agrees with Hewitson's original figure.

Pseudalmenus Chlorinda Conara n. subsp.

In a restricted area in the north-central midlands occurs the most distinctive form to be found in the collective species.

Male. Forewing above, in comparison with subsp. *chlorinda* has only a faint indication of the orange-yellow discal band, which is almost completely obliterated by scattered black scales, the basal area thinly covered with blue scales. Hindwing above with the tornal red band as restricted as in ssp. *chlorinda*, but overlaid and darkened with scattered black scales.

Beneath, ground colour dull grey, forewing with discal band of black spots 1 mm. wide extending from costa to hindmargin, the subtornal red band of hindwing is reduced to a thin line in areas 3 and 4, in areas 5, 6 and 7 it is replaced by submarginal black spots.

Forewing length 14 mm.

Female above, discal area beyond the black spot at end of cell completely overlaid with black scales, so that the orange band of ssp. *chlorinda* is only faintly indicated by a yellow-grey area. Hindwing above, uniformly black except for the tornal dull yellow-red crescentic spots in areas 1a, 2 and 3.

Beneath, discal band of forewing as broad as in male; hindwing with a broad complete discal band of black spots, narrow subtornal dull red spots in areas 1b, 3 and 4, continued as a row of black spots in areas 5, 6 and 7.

Forewing length 17 mm.

Holotype male labelled Conara, Tas. c. 700 ft. 11 Oct. 1962. R. Couchman. Allotype female labelled Conara, Tas. c. 700 ft. 30 Oct. 1962. R. Couchman; fifteen paratype males and ten paratype females from the same locality.

The aboriginal word " conara " is given as meaning coal by d'Entrecasteaux.

This is a remarkable melanic race which seems to occur exclusively in the district around Conara, certainly nothing consistently resembling the female has been found elsewhere. The first few specimens that I obtained were thought to be merely aberrations, but the dull female in which all the normal orange and red markings in other races is here sullied with black scales continues to be consistent and exclusive to this area, so that I have no doubt of its distinctiveness. Large areas of the original locality have been " pasture improved ", resulting in the complete clearing of the larval foodplant, *Acacia dealbata* and also of the *Eucalyptus viminalis* which harbours the attendant ant without which the butterfly cannot survive. In this area, as with all other Tasmanian localities, the pupa of *Pseudalmenus* has been found only under the loose bark of the *Eucalyptus* and always attended by the ant, *Iridomyrmex foetans* Clark. (I recorded this ant (1962) in error as " foetida ").

With the establishment of the subspecies *myrsilus* and *conara* the study of this species, which has extended over the past sixteen years is now nearing completion with our present knowledge of the distributional pattern in Tasmania. A detailed survey is in preparation.

PAPILIONIDAE

Graphium Macleayanus (Leach) 1814.

Leach remarks in describing this species on p. 17 of the Zool. Miscellany, "Habitat in Australasia. Mus. Dom Macleay. . . . which was discovered at Port Jackson by Mr. A. Huey". The insect depicted on plate 5, except for the broken tails of the hindwings, is of the usual form found in this district, so that Sydney must be the type locality. Almost twenty years ago my friend, the late F. E. Wilson, called my attention to the distinctions between the species as found in coastal New South Wales and that found on the Atherton Tableland in North Queensland; the western Tasmanian race is also distinctive in size and markings.

Graphium Macleayanus Wilsoni n. subsp.

Male above when compared with ssp. *macleayanus* has the basal area above white, only along the costa is it narrowly pale green, outwardly this area is not sharply defined as in the typical race and extends along dorsum almost to tornus, costal and subcostal green spots much smaller, that at end of cell 1 mm. wide, elongate.

Hindwing with faint traces only of a subterminal row of small white spots.

Beneath discal brown band and subterminal area almost unicolorous, the subterminal suffusion scarcely dividing the band at vein 3.

Forewing length 33 mm.

Female, hindwing with no trace of subterminal spots, otherwise above and beneath as in male.

Forewing length 37 mm.

Ssp. *wilsoni* is larger, lighter and with extended basal areas above and does not possess the light suffused subterminal area of hindwing beneath as found in ssp. *macleayanus*.

Holotype male labelled Kuranda, N.Q. 19-3.50. A. N. Burns. leg. F. E. Wilson, in the Couchman collection.

Allotype female labelled Kuranda, N.Q. 10 Feb. 50. D. F. Crosby, in the Crosby collection; two paratype males similarly labelled in the same collection.

Graphium Macleayanus Moggana n. subsp.

Male forewing above with basal area uniformly pale green, extending only 7 mm. along costa, outwardly clearly defined and sharply recurved towards base at dorsum.

Hindwing above, the pale green basal area less extensive than in ssp. *macleayanus*, anal lobe produced and clearly coloured brown.

Beneath discal areas of forewing black, not brown as in the typical race, and with basal pale green area restricted as above; hindwing with discal brown bands outwardly edged with white crescentic spots in areas 1 to 5.

Forewing length 25 mm.

Female above as in male, larger, hindwing with distinct white sub-terminal spots in areas 2, 3, 4 and 5.

Beneath as in male, post discal spots white, merging into a suffused subterminal band.

Forewing length 31 mm.

Holotype male labelled Florentine River, Tas. (6 miles W. of Maydena) c. 1000 ft. 10 Nov. 1963. L. E. Couchman.

Allotype female with same data.

Two paratype males similarly labelled also in my collection. With these I associate specimens from the Cuvier River-Lake St. Clair district, c. 2500 ft. 25 Dec., 1948; Mt. King William 1, 2500 ft. 16 Dec., 1962; Mt. Acropolis, 3900 ft. 16 Jan., 1945, all collected by my wife and myself.

Ssp. *moggana* is much smaller, darker and with restricted markings of distinctive shape when compared with ssp. *macleayanus* from the coastal areas of the eastern mainland States. Moggana was the word used by the Western tribes for wet or rainy, an apt name for an insect from the high rainfall western districts of Tasmania.

SATYRIDAE

Heteronympha Penelope Panope Waterhouse 1937.

Waterhouse possessed only males when describing this race in 1937, and although during the intervening years large numbers of specimens have been taken in the alpine areas of Tasmania the female has remained unknown and undescribed from the type locality. A brief hour's sunshine in almost continuous rain and sleet during the last week-end in February this year enabled my wife and I to take a number of both sexes, including two pairs *in cop.*, in grassy meadows near Daisy Dell, 12 miles north-east of Cradle Mt., c. 2800 ft.

Neallotype female, considerably smaller than the female of the lowland ssp. *diemeni* Waterhouse, forewing narrower, apex more acute, hindmargin much less bowed.

Above, ground colour of forewing is distinctly lighter than the hindwing, particularly the costal area and the spot below subapical ocellus as in the male described by Waterhouse, black markings more extended than in ssp. *diemeni*, hindwing with a somewhat elongated black subtornal ocellus, 3 mm. diameter, black subapical ocelli in areas 5 and 6 2 mm. diameter, both clearly white-pupilled.

Beneath, hindwing heavily suffused purplish, discal and submarginal bands dark and clearly defined, yellow band surrounding ocelli outlined black, pupil white.

Forewing length 23 mm.

Neallotype female labelled Daisy Dell, 12 miles N.E. Cradle Mt., Tas. c. 2800 ft. 29 Feb., 1964. L. E. Couchman. Five paratypes similarly labelled in my collection.

Specimens from the higher alpine areas of western and central Tasmania may be referred to this subspecies, I possess specimens from Miena, 3400 ft. 21st February to 2nd March, 1952; from the Steppes, 2300 ft. during the same period; Lake St. Clair, 2300 ft. 26th January, 1953, (males only); Waratah, c. 2000 ft. 26th January, 1961 (males only); St. Valentine's Peak, c. 2600 ft. 25th Janu-

ary, 1961. Females from Mt. Barrow, 2475 ft. 9th February, 1949 N. B. Tindale, do not differ, and even from high altitudes on Mt. Wellington the females at least are not appreciably different.

ACKNOWLEDGMENTS

I continue to be indebted to many friends, A. N. Burns and A. Neiboiss in the National Museum of Victoria, D. F. Crosby for the loan of specimens, Deniss Reeves for constant help and the preparation of the photographic plate, A. M. Hewer for continued interest and companionship in the quest for Tasmanian butterflies.

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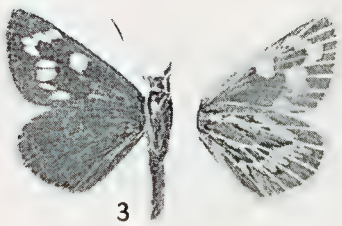

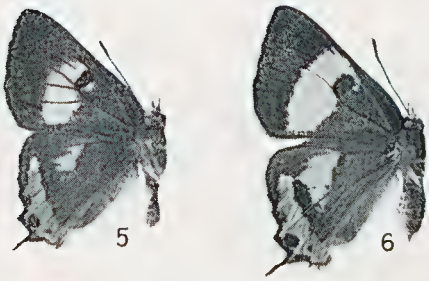

Photos – D.M. Reeves.

PLATE I.

Fig. 1.—*Orcisplanus munionga larana* Couchman 1962. Female upper and underside. Marrawah, Tasmania.

Fig. 2.—*Hesperilla mastersi marakupa* n. ssp. Female holotype, upper and underside. Bridport, Tasmania.

Fig. 3.—*Anisynta albovenata weemala* Couchman 1954. Male paratype, upper and underside. Gunnedah, N.S.W.

Fig. 4.—*Neolucia serpentata lavara* Couchman 1954. Male holotype, upper and underside. Cambridge, Tasmania.

Fig. 5.—*Pseudalmenus chlorinda myrsilus* (Doubleday and Hewitson) [1851]. Neallotype male, upperside, Saltwater River, Tasmania.

Fig. 6.—*Ps. chlorinda myrsilus* (Doubleday and Hewitson) [1851]. Female upperside. Saltwater River, Tasmania.

Fig. 7.—*Ps. chlorinda conara* n. ssp. Male holotype, upperside. Conara, Tasmania.

Fig. 8.—*Ps. chlorinda conara* n. ssp. Female allotype, upperside. Conara, Tasmania.

Fig. 9.—*Graphium macleayanus wilsoni* n. ssp. Male holotype, upper and underside. Kuranda, North Queensland.

Fig. 10.—*Graphium macleayanus moggana* n. ssp. Male holotype, upper and underside. Florentine River, Tasmania.

Figures 1 to 8 one and a half times life size, figures 9, 10 life size.

Papers and Proceedings of the Royal Society of Tasmania, Volume 99

NOTES ON SOME TASMANIAN PINES. I. SOME LOWER TERTIARY PODOCARPS

By

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(With two plates and 11 text figures.)

ABSTRACT

Podocarps from a new locality are described under the following names, *Podocarpus strzeleckianus* sp. nov. (Eupodocarpus), *P. tasmanicus* sp. nov. (Stachycarpus), *P. setiger* sp. nov. (Dacrycarpus), *P. goedei* sp. nov. and *P. acicularis* sp. nov. (of unknown Section), *Microstrobus sommervillae* sp. nov. and *Coronelia molinae* Florin. Of these *P. tasmanicus, P. strzeleckianus,* and *Coronelia molinae* represent sections or genera previously unknown in Tasmania, *M. sommervillae* represents the first fossil record of *Microstrobus.* Some features of the distribution of the Podocarpaceae are discussed.

INTRODUCTION

Conifers from the Tasmanian Tertiary were discussed by Florin (1940), and further studies (mostly of pollen) have since been undertaken by Cookson (1953), Cookson and Pike (1953, 1953a, 1954) and Cookson and Duigan (1951). There still are not many records of macrofossils. Lately Mr. Albert Goede, University of Tasmania, discovered a rich Lower Tertiary locality at Buckland, and with Mr. J. L. Davies, most generously turned the material over to me. I thank them for this courtesy. The following covers some of the Podocarpaceae, most of which belong to genera or sections already known from pollen, but some new records are included.

MATERIAL AND AGE

The Material. The material consists of detached leaves and fragments of leaves and shoots in a soft clay. At its best the clay is almost solid plant matter. The richest blocks were found loose in the bed of the Tea Tree Rivulet, and the possibility was considered that they might not belong with the strata on which they were resting. However, with Mr. Goede's help other material with, in part, the same flora, was found in situ. It is most likely that all comes from the same deposit.

The plant beds occur as lenses in lacustrine clays, and the material, is, presumably, the " sweepings " of the forest floor carried into a lake or other still water.

To isolate the plants the clay was soaked in dilute nitric acid (about 10% HNO_3), when it broke down, and the plant material could be decanted off from the remaining clay. The fragments were then divided into sorts of leaf, and cuticles prepared from each sort. Although the final identification had to be done on the cuticle, after a while it became possible to determine the fragments unmacerated in about four cases out of five.

The locality of all species is: Bed of Tea Tree Rivulet, about two miles upstream from the Gatehouse Marsh causeway, Buckland, Tasmania.

For comparison, herbarium material and cuticles were examined from the following species: *Acmopyle pancheri, Dacrydium biforme, D. colensoi, D. kirkii, D. franklinii, D. falciforme, D. taxoides, D. cupressinum, D. intermedium, D. elatum, Microstrobus niphophilus, M. fitzgeraldii, Microcachrys tetragona, Podocarpus andinus, P. montanus, P. spicatus, P. ladei, P. ferrugineus, P. ferruginoides, P. totara, P. lawrencei, P. acutifolius, P. hallii, P. nivalis, P. gnidioides, P. minor, P. vitiensis, P. dacryiodides, P. imbricatus, P. elatus, P. spinulosus, P. drouynianus, P. latifolus, P. henkelii, P. falcatus,* and *P. gracilior.*

Age.—Among the material are specimens of *Coronelia molinae* Florin. This species is only known from the Eocene Concepcion Coal Measures of Chile. Dr. S. Duigan kindly examined the pollen from one sample and found *Ephedra notensis* and *Triasaccites micropertus,* both only known so far from lower Tertiary or earlier localities. The evidence is not as strong as would be desirable, but a Lower Tertiary age seems most likely at present, possibly Eocene.

Nomenclature. The nomenclature of the fossils is unsatisfactory. Several species of podocarp pollen have been described (e.g. Couper 1960), and it is highly likely that some at least were produced by the same trees as produced the foliage here discussed. One is forced, however, to make a new name for the foliage, in absence of knowledge of the parent plant of the pollen. When the male cones are found, it is to be hoped that some of the names here suggested can be abandoned.

Throughout these notes type and figured material is referred to by its registration number in the collections of the Department of Geology, University of Tasmania, where it has been deposited.

FIG 1.—*Dacrydium taxoides*, A-D, I; *D. falciforme*, H; *Podocarpus ferrugineus* E; *P. dacrydiodes*, F; *P. vitiensis*, G; *P. minor*, J; *P. falcatus*, K.

A-D: Leaf bases. A, B, of a leaf borne edge on to the shoot and scarcely twisted; C, D, borne flat on and strongly twisted x 15.

E-K: Portions of shoots, to show leaf arrangement. F, note spirally inserted leaves flattened into one place with adjacent leaves pointing in the same direction.

E, G x 1.5, I, J x 1; H x 0.5; K, 0.75; F x 10.

DESCRIPTIONS

Family Podocarpaceae

Genus **PODOCARPUS** L'Herit

Section: *Eupodocarpus*, sub-section D Gray

PODOCARPUS STRZELECKIANUS sp. nov.

Pl. I C; Figs. 2 A, B, D, E, 6L-T.

Type specimen (Holotype): University of Tasmania, 81917 see Pl. I C.

Diagnosis. Leaf 2-3 mms. wide, about 1.5 cms. long, probably borne spirally on shoot and leaves not or only slightly twisted into two rows. Leaves monomorphic (as far as known). Leaves flat, of moderately thick substance, margins scarious, and showing small shoulders near the apex, but parallel sided over most of their length. Short petiole present, showing only slight twisting, more or less symmetrically inserted; leaf widening to full width within 1-3 mm. of petiole. Apex pointed, but not acuminate. Midrib projecting very slightly on stomatiferous side of leaf.

Cuticle 1.5-2 μ thick, but thinner over stomatal zones. Leaf hypostomatic, showing longitudinally orientated stomata close set in two narrow stomatal zones. Epidermal cells outside stomatal rows more or less elongated, 70 μ x 20 μ, outlines thin about 1.5 μ, nearly or quite straight. In stomatal bands cells about 50 μ x 20 μ, outlines thinner, and straight. Cells over scarious margin somewhat wider than over rest of leaf. Cuticle devoid of papillae or other ornament.

Stomata lying in rows about 12 (5-16) stomata high, stomatal zone showing 5-7 such rows across its width. Stomatal rows lying in 2-4 groups across width of a stomatal zone; within such a group laterally adjacent stomata having their lateral subsidiary cells touching; but having 1-3 rows of cells lying between any two such groups. Adjacent stomata in a row normally sharing a terminal subsidiary cell. Lateral subsidiary cells normally two, rarely three; stomata on edge of a stomatal group sometimes amphicyclic, other stomata rarely amphicyclic.

Stomatal aperture more or less rectangular, 20 μ x 10 μ, often distinctly elongated. Florin ring present. Surface of guard cells thinly cutinised, and scarcely thicker cutin present around the aperture.

Description. The material consists of broken leaves only no complete or attached leaf has been seen. The longest specimen is 1 cm. long (fig. 6 Q), and it is the basal part. By analogy with living conifers, it is likely that the presence of a petiole sometimes somewhat twisted (fig. 6, O, P.), indicates that the leaves were spirally borne and showed a slight tendency to be in two rows. In a good many hand specimens, the stomatal zones can clearly be seen, and between them the midrib projects very slightly (figs. 6, P, N); these specimens also show that the leaf was flat, or perhaps rarely slightly concave (fig. 6 R), and it appears not to have tapered towards the margin. The scarious margins, and its shoulders can be seen both on the intact specimen (figs. 6 L, M, S. T) and also on the cuticle as differently shaped cells.

No small leaves of this species were seen; it is probable, therefore that like e.g. *P. lawrencei, P. strzeleckianus* did not show a regular and prolonged series of small to large leaves in each year's increment.

Specimens from all parts of the leaf were available for maceration no stomata on the upper leaf surface were seen. The form of the stomatal zones is shown in pl. I. C, they were narrow, and sharply set off from the margins and midrib. They formed, however, a line of weakness in the cuticle, and were usually torn, often before manipulation. The arrangement of stomata within the zones is shown in figs. 2 A, D and given in the diagnosis. An important point is that the cell outlines were either straight, or only the slightly wavy (figs. 2 E). The Florin ring is visible on every stoma examined, but most plainly on the lateral margins of the stomatal pit (fig. 2 A, E).

Classification. Podocarpus strzeleckianus is believed to have small (1-2 cm.) leaves, probably spirally borne, petiolate with a scarious margin, hypostomatic with the stomata disposed in two well defined zones. This sort of leaf, according to Laubenfels (1953) is found chiefly in the Taxaceae, Pinaceae, Cephalotaxaceae and Podocarpaceae. The first three are unlikely, for *P. strzeleckianus* shows points of difference from all, e.g. it lacks the cuticular papillae of the Taxaceae (Florin 1931, 1958,). They are also unlikely on geographical grounds (Florin 1963). On the other hand it agrees well with certain podocarps, especially those of the subsection D of section Eu-podocarpus (Gray 1956, see also Florin 1931; Wasscher 1941, Orr 1944). The other sections can be disposed of: Dacrycarpus has bilateral juvenile leaves and awl-like adult ones, Microcarpus scale leaves, Nageia several veins per leaf, Polypodiopsis a special leaf arrangement and nearly equally amphistomatic leaves, Afrocarpus has amphistomatic leaves, and Sundacarpus large leaves. The section Stachycarpus is a possibility, but in this section the hypostomatic species appear to have rather wide stomatal zones (Florin 1931 and cf. figs. 3 A, D) and strongly wavy cell outlines. Of the other subsections of Eu-podocarpus, sub-section B has no Florin ring (this subsection contains the mainland Australian species *P. spinulosus P. elatus* and others), while sub-section E (*P. rostratus*) has minute leaves. Sub-sections A and C appear to be characterised by having rather large leaves, that is 2 cms. or more long, and this makes them unlikely, though remaining perhaps a possibility. Subsection F has large leaves and also no Florin ring (Bucholtz and Gray, Gray 1948, 1953, 1955, 1956, 1958).

A difficulty might be that the cell outlines are usually (but not quite always) straight; *P. gnidioides* is nearly the same, however. It might be argued that the scarcely projecting midrib is a difficulty. I doubt this, for in a species such as *P. lawrencei* described as having a strongly projecting midrib, *living* material, or wet rotten leaves, do not show a projecting midrib; what happens is that as material dries, e.g. on an herbarium sheet, the tissue under the stomatal zones collapses.

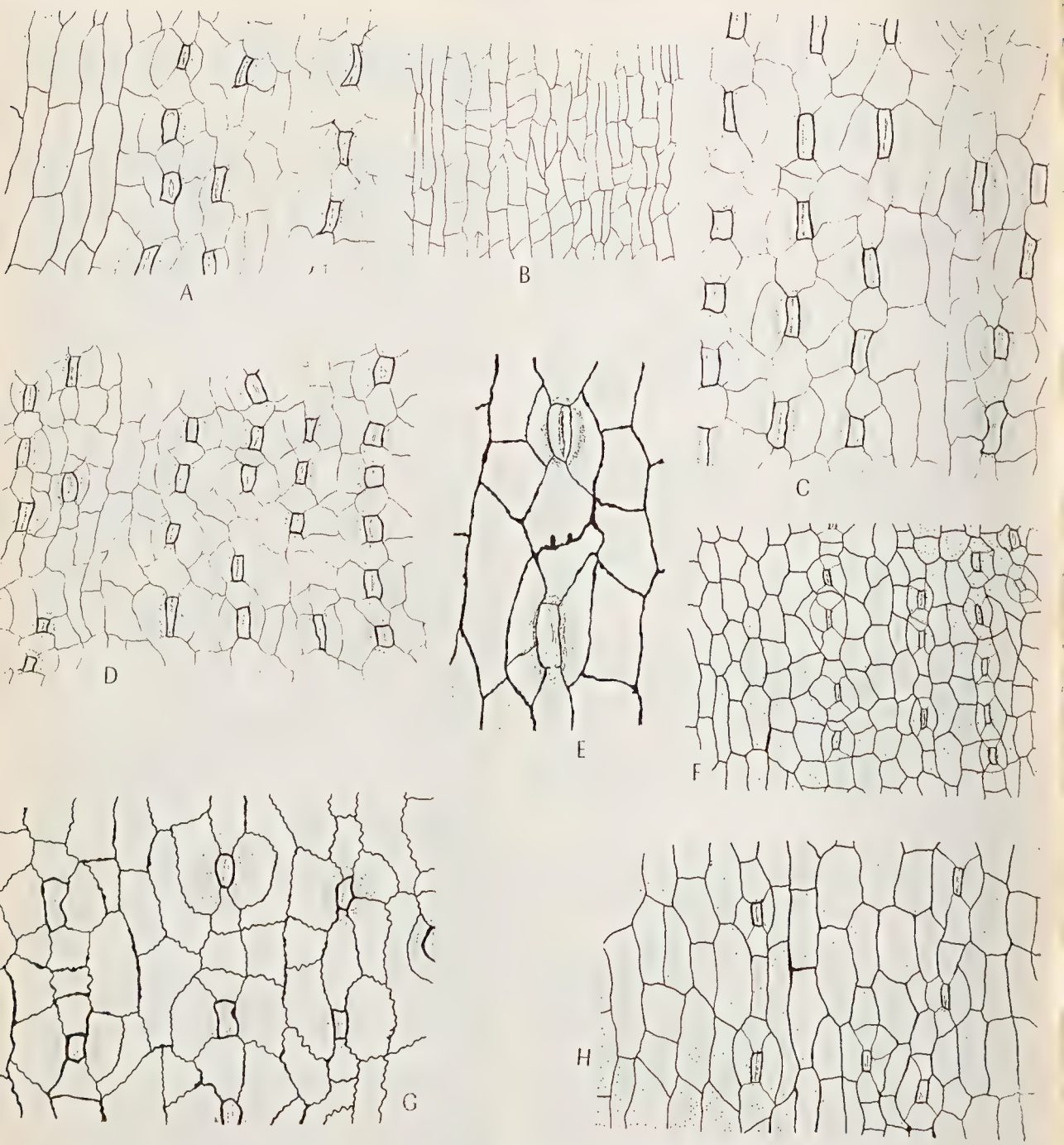


FIG. 2.—*Podocarpus strzeleckianus*, A, B, D, E; *P. gnidioides*, C; *P. tasmanicus*, F, H; *P. totara*, G.

A, D: Lower cuticle, with stomatal rows and (A, to left) margin. x 350. 81916.
B: Upper cuticle, margin marked by arrow, showing differently shaped cells. x 170. 81916.
C: Lower cuticle, note similarity to A and D. Herb. N.S.W. x 350.
E: Stomatal details and sinuosities of cell outlines. x 600. 81916.
F, H: Upper and lower cuticle, showing stomatal arrangement in stomatiferous zones. x 230. 81909.
G: Lower cuticle, showing stomatal arrangement and sinuosities on outlines. Herb. N.S.W. x 350.

It is not possible to compare *P. strzeleckianus* specially closely with any one of the species placed in sub-section D. In showing a scarious margin and a nearly flat leaf *P. strzeleckianus* resembles *P. totara* and is distinct from e.g. *P. lawrencei*. The cuticles of sub-section D seem to show two intergrading sorts of stomatal arrangement in the zones; either the stomata are more or less evenly scattered, and without touching lateral subsidiary cells (*P. totara, P. hallii, P. lawrencei, P. nivalis* fig. 2 G) or else the stomatal rows are grouped into subzones within which lateral subsidiary cells of adjacent stomata do (often) touch, each sub-zone being separated by a file one or two cells wide from its neighbours (figs. 2 C). This is the disposition most usually seen in *P. strzeleckianus* (fig. 2 D) and it is also seen in *P. gnidioides* and *P. acutifolius*.

Sub-section D has not been definitely reported fossil from the early Tertiary before. Florin (1940: 33) considered the *Elatocladus kerguelenensis* Seward and Conway (1934) was probably of the group, close to *P. nivalis*, but in absence of microscopic detail did not make a firm identification. It would seem likely that this sub-section was already defined by the Tertiary, in at least one of the areas it now occupies, but it is very doubtful whether the species now extant were then in existence.

Section: *Stachycarpus* Endlicher, sub-section *Idioblastus* Bucholtz and Gray.

PODOCARPUS TASMANICUS sp. nov.

Pl. I A; Figs. 2 F, H; 3 A, D, E; 6 A-K; II A, B.

Type specimen (Holotype)—University of Tasmania No. 81905. See figs. 6 H, I.

Diagnosis. Leaves 2-3 mm. wide, about 1 cm. long. Almost certainly spirally borne, and larger leaves very probably twisted into two rows. Leaves dimorphic, size ranging from small oval leaves 2.5 x 1.5 mm. to size given. Leaves flat, of thick substance tapering to a thin, but not scarious nor inrolled, entire and even margin.

Petiole, or (at least) a basal contraction of the leaf present, up to 2 mm. long and in larger leaves asymetrically inserted, leaf widening within 3 mm. to maximum width thereafter more or less parallel sided, or rarely bulging slightly. Apex pointed or blunt. Midrib obscurely visible on lower leaf surface.

Cuticle 2-2.5 μ thick more or less same thickness all over. Leaf unequally amphistomatic, showing on lower surface two wide stomatal zones separated by a distinct non-stomatiferous zone over the midrib. On upper surface, stomata up to about half as numerous as on lower surface, usually more or less scattered, especially numerous in the midrib region; distally, sometimes showing imperfect separation into two zones. Epidermal cells outside stomatal bands elongated longitudinally, 65 μ x 24 μ, outlines slightly wavy, or pierced by holes, or (most often) straight, 5 μ thick. Epidermal cells in stomatal zones about 38 μ x 30 μ, otherwise similar to the rest. Cuticle devoid of papillae or other ornament.

Stomata lying in rows about 15 (7-20) stomata high, and stomatal rows separated from one another by one or two rows of cells so that lateral subsidiary cells of adjacent stomata do not touch. Within rows stomata usually having their own terminal subsidiary cell, terminal encircling cell either absent or shared between adjacent stomata. Usually two lateral subsidiary cells, but three or four seen, stomata most often amphicyclic with respect to lateral subsidiary cells, or stomata in adjacent rows sharing a lateral encircling cell. Stomata on upper leaf surface as those on the lower.

Stomatal aperture rounded, or rectangular, 14 μ x 8 μ, sometimes almost square, Florin ring present, but sometimes indistinct. Guard cells feebly cutinised, even round the aperture.

Description. As with *P. strzeleckianus* attached leaves have not been seen, but again as in that species, the presence of a more or less strongly twisted petiole suggests a spiral leaf arrangement, in this case more definitely modified by twisting into two rows. There are a few complete probably small leaves (fig. 6 A, C, H) but more fragments; the leaf seems to have been a small one, however, i.e. less than 2 cms. long. There is a steady gradation between the small almost scale like leaves and the larger ones, and, except for size and the position of the petiole (or basal contraction) there is no difference between the different sorts of leaf (fig. 6 C, D). A similar gradation can be seen over the years increment in *Podocarpus ferrugineus, P. ladei* and *P. ferruginoides* and doubtless others (figs. 1 E, J). It is unlikely that *P. tasmanicus* was like e.g. *Sequoia sempervirens* in which the change over from small scale leaves to full sized ones tends to be abrupt.

In this case, as in *P. strezeleckianus*, I assume that the surface upon which the midrib projects, and upon which the majority of stomata lie is the lower; this seems to be only reasonable (Florin 1931, Laubenfels 1953).

In most leaves the margin shows one or two cell rows beneath which the substance is thin, almost to the point of forming a scarious margin (fig. 6 H, I). This feature is not accompanied by any difference in the epidermal cells, and I suggest it probably represents a tapering margin (e.g. *P. ferrugineus*) as against a thick one (e.g. *P. lawrencei*).

The cuticle is somewhat variable, especially in the number of stomata on the upper leaf surface (Pl. 1 A and figs. 2 F, H). This feature however, is also variable in the material of living *Podocarpus* species, and I am inclined to disregard it, though it is always possible that the material is composite. On the under surface the non-stomatiferous zone over the midrib (fig. 11 A, B) appears to be constant and well marked. The cell outlines are shown in figs. 3 C. On the other hand the stomata were similar in all the material, the chief variation (which was not great) being in the shape of the stomatal pit (figs 3 A, D). The Florin ring was sometimes obscure, though I think probably always present, and of about the same size all round the stoma.

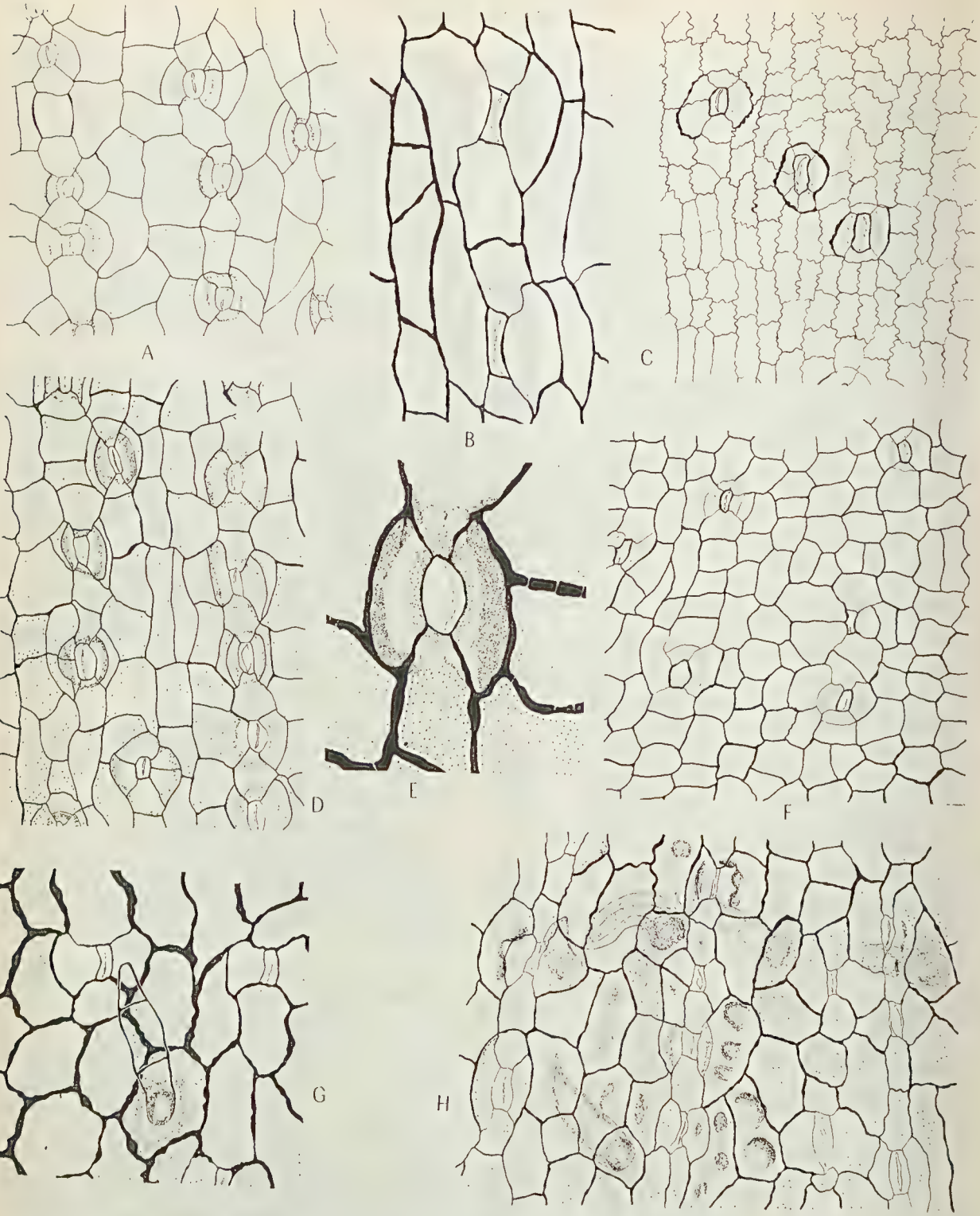


FIG. 3.—*Podocarpus tasmanicus*, A, D, E; *P. acicularis*, B; *P. andinus*, C; *P. ferrugineus*, F; *Coronelia molinae*, G, H.
A, D: Cuticle from large and small leaf respectively, showing varying appearance of stomata and epidermal cells. x 430. A, 81911. D, E, 81912.
B: Somatal details and subsidiary cells. x 600. 81925.
E. Stomatal details, showing Florin ring, and holes in the cell outlines. x 600.
C, F: Upper cuticle showing stomata; note straight cell outlines in F, C. Bot. Gdn., Hobart; F. Herb., N.S.W. x 230.
G: Stomata, cell outlines and a large hair. The cells scarcely are papillate. x 430. 81898.
H: The same, note large papillae on some cells. x 430. 81898.

P. tasmanicus and *P. strzeleckianus* superficially are similar, but can fairly readily be told apart, on the hand specimen by the form of the margin, and by the appearance of the stomatal bands, which are scarcely visible in *P. tasmanicus*. The cuticles separate them without difficulty, there is, indeed scarcely a feature in which confusion could arise.

Classification. Podocarpus tasmanicus is believed to have had spirally disposed leaves, probably twisted into two rows, and grading over gradually from small to large leaves but all more or less of the same sort. The leaves were small (1-2 cm.) flat, petiolate, unequally amphistomatic, with stomata lying in two wide rows on the under surface, but more scattered above, and all longitudinally orietated. It seems to me that this combination of characters again indicates the Podocarpaceae, genus *Podocarpus*. Following the argument given for *P. strzeleckianus*, I suggest that *P. tasmanicus* is likely to belong to the Section Stachycarpus.

It is possible that these leaves might be the juvenile leaves of a *Dacrydium species*, but this is I think unlikely. There are fewer stomata on the upper leaf surface than appears to be usual in *Decrydium* juvenile leaves, and there is evidence that the leaves were twisted into two rows. The stomatal zones are also more definite than appears to be usual in *Dacrydium*.

Section Stachycarpus has been divided into two sub-sections by Bucholtz and Gray (1952) as follows:—

Idioblastus—with idioblasts, and an unequally amphistomatic leaf (*P. ladei, P. ferruginoides* and (originally) *P. distichus*).

Eu-prumnopitys—without idioblasts, and hypostomatic, except *P. andinus* and *P. ferrugineus* (described as hypostomatic, but see p. 7).

The fundamental character is the presence of idioblasts. These would be difficult to demonstrate in fossil material, though they might be visible in partly macerated leaves (cf. Harris 1958). In fact I have been unable to see anything that could be called an idioblast, but this is not conclusive.

As regards stomatal distribution there is difficulty, *P. tasmanicus* approaches *P. ladei* in number of stomata on the upper leaf surface, and like *P. ladei* shows a definite non stomatiferous zone over the midrib, though more definite than *P. ladei* (fig. 10 A, F). There are still not nearly as many stomata on the upper surface in *P. tasmanicus* as *P. ladei*. *P. tasmanicus* shows more stomata on the upper leaf surface than *P. ferruginoides* and *P. distichus*, and differs further from these leaves in showing a definite non-stomatiferous zone over the midrib (figs. 11 E). It resembles *P. ferrugineus* in this (fig. 11 C) though having more stomata on the upper leaf surface. *P. ferrugineus* also may show, like *P. tasmanicus*, nearly straight cell outlines, unlike *P. ferruginoides*, but again like *P. ladei*. The leaf margin is also believed to have been tapering as in *P. ferrugineus*.

On the whole I think comparison is closest with *P. ladei*, and *P. tasmanicus* is accordingly placed in sub-section Idioblastus. It is interesting that *P. ladei* has the smallest idioblasts of the three species of the sub-section. It is also interesting that there is the uncertainty in classification (there is not in dealing with the cuticles of the living species, so far as I have seen them): it might suggest that in the early Tertiary the difference between the two sub-sctions was not so great as at present. At present *P. ladei* grows in a small area near Atherton (Queensland) *P. ferruginoides* and *P. distichus* in New Caledonia, and *P. ferrugineus* is confined to New Zealand.

Note on the leaf anatomy of *Podocarpus ferrugineus* Don.

Podocarpus ferugineus is usually stated to be amphistomatic in the juvenile leaves, but hypostamatic later (see e.g. Griffin 1908, Florin 1931; 362-363, Bucholtz and Gray 1951; 351). In the material available to me this is not entirely so. I have seen only one specimen that was hypostomatic, coming from the Botanical Gardens, Melbourne; and it showed on the small leaves starting the years increment, a very few (1-5) stomata on the upper surface. This specimen was unusually small leaved, and also showed unusually tightly packed stomata in the stomatal rows. The remaining material always showed some stomata on the upper surface, sometimes quite numerous at the apex, (fig. 11 C. D) down to only a very few. For the most part the stomata reached less than a quarter the way down the leaf, but in one specimen (from Upper Hutt) they reached about three quarters way down the leaf, and this specimen also showed a band of elongated cells over the midrib. In general, where there were stomata on the upper leaf surface the cell outlines were very nearly straight (fig. 3 F). The stomata were mostly in the region of the midrib, and in details, like those on the lower surface (see Florin 1931; pl. 21 fig. 6).

It would seem better to describe the stomatal arrangement of this tree as "unequally amphistomatic, but sometimes hypostomatic; stomata on upper surface few, lying towards apex, rarely seen more than a third way down the leaf". In its stomatal arrangements *P. ferrugineus* comes very close to the sub-section Idioblastus e.g. *P. ferruginoides*. It differs from *P. ferruginoides* and *P. distichus* in showing (normally) a distinct non stomatiferous zone over the midrib. Such a zone is also present in *P. ladei*, but possibly less pronounced than in *P. ferrugineus*. (Figs. 11 C-F). The absence of idioblasts is ultimately the only reason for placing *P. ferrugineus* in sub-section Euprumnopitys.

Material Examined.

(1) Geological Survey of New Zealand: exact locality not given.

(2) National Herbarium, New South Wales:

(*a*) from Upper Hutt,

(*b*) from Huia near Auckland,

(*c*) tree growing in Melbourne Botanic Gardens,

(*d*) no locality beyond New Zealand,

(*e*) no locality beyond New Zealand.

FIG. 4.—*Podocarpus setiger*, A, B, C; *Coronelia molinae*, D; *Microstrobus sommervillae*, E, G, H; *M. niphophilus*, F; *M. fitzgeraldii*, I.

A, B: Parts of two leafy shoots. x 10. 81918, 81919.

C: A rather short leaf, apex broken off. x 10. 81921.

D: A leaf base, note widest part of leaf very near base. x 10. 81899.

E, K: Lengths of shoot, with leaves of varying size. Heavy stipple marks where leaves are missing, all x 15. E, 81902; G, 81900; H, 81903; F and K, Herb. Univ. Tas.

(3) Arnold Arboretum, Cambridge, Mass. (annotated by late Prof. J. Bucholtz):

(*a*) Longwood Range, New Zealand Cockayne, 9096,
(*b*) Bay of Island, New Zealand,
(*c*) New Zealand, Wilson S.N. 2/28/21.

(4) Botanic Gardens, Dunedin: in cultivation.

Section: *Dacrycarpus* Endlicher.

PODOCARPUS SETIGER sp. nov.

Pl. 2 A; Figs. 4 A, B, C; 5 B, E; 7 F; 10 A, B.

Type specimen (Holotype); University of Tasmania. No. 81908 see Fig. 4 A.

Diagnosis. Bilateral leaves only known; these about 6 mm. long (4-8 mm.) and 2 mm. wide (1-2.5 mm.); straight or slightly falcate, apex acute to mucronate, mucro forming angle of about 60° with axis. Base contracted, leaf at base about 1.5 mm. wide, contraction seen only on upper leaf edge, leaf as a whole decurrent, and probably borne in two ranks on the axis. Midrib prominent, asymmetrical, lying nearer lower leaf edge, substance of leaf bulging somewhat over midrib, but leaf otherwise flat and (probably) thin in life. Edges entire, showing about 10 stiff cutinised unicellular bristles along their length.

Cuticle amphistomatic, stomata much more numerous on one pair of flanks than on the other, and borne in four extremely distinct narrow zones. Cells outside stomatal zones elongated, forming parallelograms or sometimes rather wider at the ends than in the middle, about 140 μ x 40μ. Outlines distinct, pierced but not wavy. Within stomatal zones cells less elongated, about 50 μ x 30 μ, outlines finer. Characters of cells maintained in stomatal zones whether stomata present or not. Stomata lying in narrow rows, 20 or more stomata long, and stomatal zone at any point 3-7 (mainly 4 or 5) stomata wide. One pair of flanks showing fewer stomata, stomata mostly present near apex; cells looking like guard cell and subsidiary mother cells forming most of the cells in the zones. Stomata unequally amphicyclic, or two adjacent stomata showing a common encircling cell; adjacent stomata in a row normally showing a common terminal subsidiary cell. Lateral subsidiary cells most often two, rarely 3 or 4. Stomatal pit rectangular, about 20 μ x 7 μ, guard cells feebly cutinised even next to aperture. Surface of subsidiary cells flat.

Margin showing a few (up to 12) bristles along its length. Bristles arising from a single cell, unicellular, about 70 μ long, thickly cutinised except at base, which is hollow, orientated same way, pointing towards leaf apex.

Description. Three specimens showed leaves still attached to the parent shoot, indicating that they were bilateral (figs. 4 A, B). The leaf seems to have been rather uniform in its external morphology, the upturned apical point is sometimes missing, however. There is variation in the extent to which the base is contracted, if it is, the contraction takes place in that part of the leaf above the midrib (figs 4 A-C). There is no sign of wrinkling over the midrib, so I suppose the leaf was flat in life, as it is now in the fossil. The cuticle is highly characteristic. The chief features are: (1) the highly distinct stomatal zones, containing several stomatal rows, (2) the tendency for most stomata to lie on one pair of flanks, but the existence of the stomatal rows, only devoid of stomata, on the other pair of flanks (fig. 10 B, pl. 2 A), and (3) the bristles. The tendency for the stomata to lie on one pair of flanks might perhaps indicate that the leaves were borne at an angle to, and not parallel with, the illumination. The features of the stomata are given in figs. 5 B, E; 7 F; 10 A, B.

Classification. The leaves of *P. setiger* are clearly bilateral, and of living groups showing bilateral leaves, the stomatal arrangement and form agree only with *Podocarpus* sect. Dacrycarpus. I have not, however, succeeded in finding the bifacial foliage that one might expect also to occur. Perhaps as in *P. imbricatus*, most of the leaves were bilateral, borne on foliar spurs.

Pollen of the section Dacrycarpus is known from several Tertiary localities (Cookson and Pike 1953, Couper 1960), and *Podocarpus praecupressinus* and *Podocarpus* sect. Dacrycarpus sp. (Selling 1950) have been described. Cookson and Pike (1953) emphasize the difficulty of distinguishing vegetative shoots of the section Dacrycarpus, but while acknowledging the uncertainty, I think comparison can be pressed further than they are willing to go.

P. setiger differs from *P. praecupressinus* Ett. in that (1) its bilateral leaves are about twice as big, (2) it has stomatal zones 4 or 5 stomata wide, as against only 1 or 2 (rarely 4, see pl. 2 fig. 20), (3) the stomatal pit is more nearly rectangular, and (4) it has bristles along the margin, lacking in *P. praecupressinus*. Among living species, none (so far as I can discover) show the bristles on the margin. However *P. javanicus* comes close in stomatal arrangement (Florin 1931, pl. 29 fig. 10) showing dense massed stomata in zones, as opposed to rather well separated rows in the zones. *P. imbricatus*, however, links the two situations. These two species are sometimes identified.

P. praecupressinus seems to me to be very close to the New Zealand species *P. dacrydioides* and exceedingly close to (if not identical with) *P. inopinatus* (compare Florin 1931 pl. 2; pl. 15 fig. 8; pl. 18 fig 4, 1940: pls. 5 and 6; and Cookson and Pike 1953 pl. 1 figs. 2, 3; pl. 2 figs 20, 24); but *P. setiger* compares with the more tropical *P. javanicus*. As shown by others (e.g. Selling 1950) the early Tertiary seems to have contained (in part) a mixture of forms now either in the tropics or in temperate regions.

Genus *Podocarpus* l'Herit. (Section unknown)

PODOCARPUS GOEDEI sp. nov.

Pl. 1 B. Figs. 8 C-I; 9 J-T; 10 C.

Type specimen (Holotype); University of Tasmania Nos. 81928a. see Figs. 8, 9, H.

Diagnosis. Leaves bilateral, but (probably) borne in opposite or nearly opposite pairs. Leaf bases usually contracted to an angular petiole, sometimes twisted one pair of flanks over the other, so that

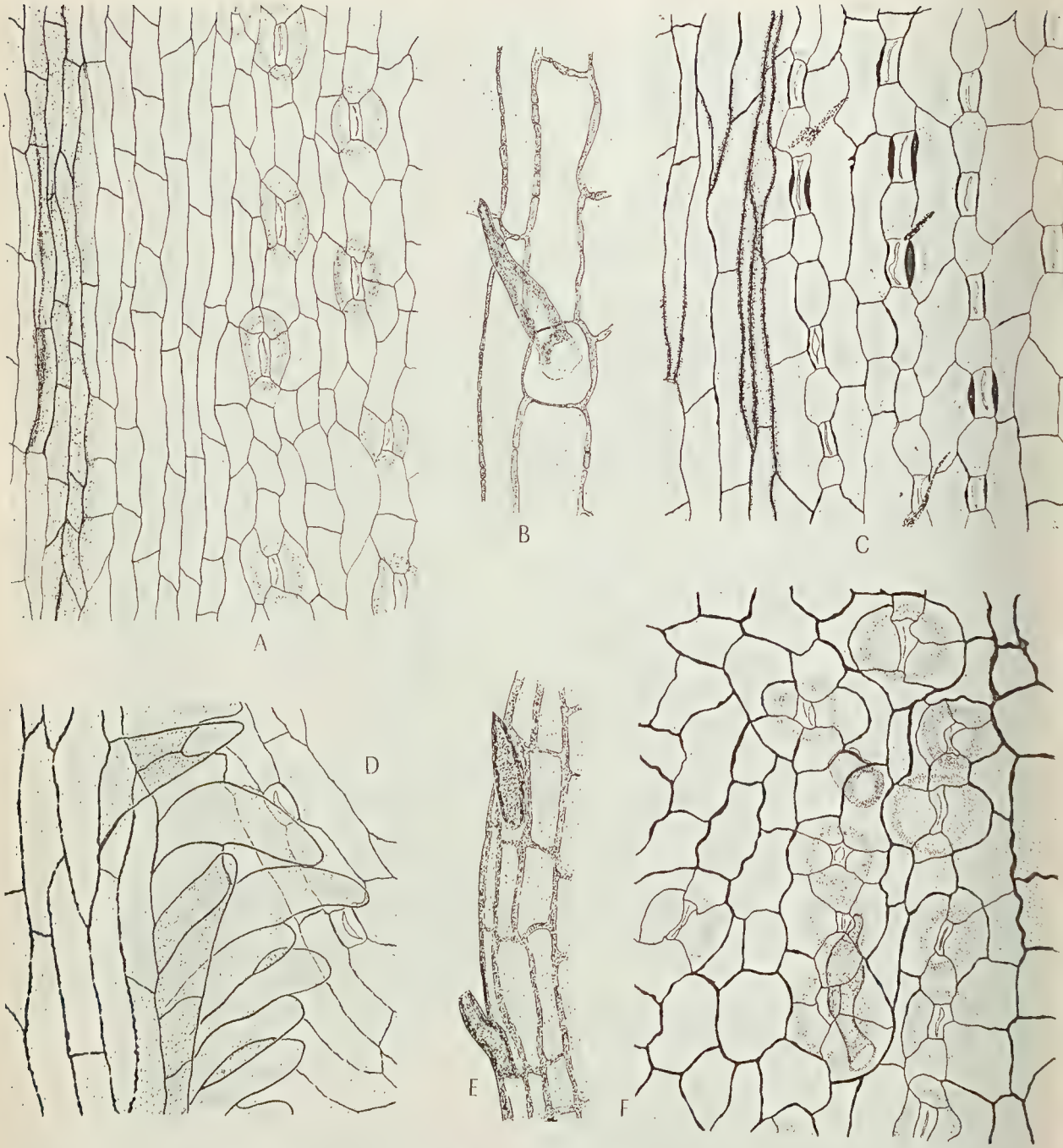


FIG. 5.—*Podocarpus acicularis*, A; *P. setiger*, B, E; *Microstrobus sommervillae*, C, D; *Coronelia molinae*, F.

A: Cuticle showing stomatal arrangement and marginal zone. x 350. 81926.
B, E: Hairs from leaf margin, small (un-macerated) and, B, larger (cuticle only). B x 230, 81922; E x 430. 81918.
C: Cuticle upper surface, stomata and marginal zone. x 650.
D. Margin with processes, lower cuticle (left), note pierced cell outlines. x 650.
F: Cuticle, with closely massed stomata, with Florin ring. x 430.

leaves (probably) sometimes showed one pair of flanks pointing upwards, the other pair down. Leaves flat, thick, midrib obscurely visible on one surface only, often falcate. Margins even, parallel over most of the length of the leaf, contracting gradually at base, but more or less suddenly to acute apex. Leaves 6-15 mm. long and 1.5-3 mm. wide.

Cuticle about 3 μ thick, amphistomatic, two surfaces almost indistinguishable, stomata distributed in long vague rows, or in short groups of 2 or 3 within rows, over the whole surface except a band at each margin, midrib not visible on cuticle. Over most of leaf cells about 50 μ x 30 μ, in marginal bands elongated, about 50 μ x 18 μ, cells rectangular more or less in rows, cuticle surface flat, or, especially along margins, showing small thickenings, several to a cell. Cell outlines distinct, straight or very slightly undulating, devoid of perforations or projections. Stomatal rows irregularly placed, 3-20 (usually 10-15) stomata high, stomata orientated longitudinally. In a row adjacent stomata often sharing common terminal encircling cell, or encircling cell absent, rarely sharing a common terminal subsidiary cell. Most often two lateral subsidiary cells, encircling cells usually present. Florin ring present and distinct. Stomatal pit overhung by subsidiary cells, aperture rounded or slightly elongated; guard cell surface fairly strongly cutinised.

Description. The manner in which the leaves were borne is left over for discussion with *P. acicularis* (p. 11). The leaf contracts to an angled petiole, but the transition is gradual (fig. 9 Q. R) suggesting that the leaf may have been thick. By analogy with living conifers the obscure midrib and the absence of a non-stomatiferous band in the cuticle over the midrib also suggest a thick leaf (pl. 1 B, figs. 11 G). The cuticle from the two surfaces of the leaf is nearly indistinguishable; the only difference I can see is that one (presumably the lower) may be slightly thinner. This seems to be unusual, normally some difference is discernible (pls. 1 A, C; 2 B and see Florin 1931). At the apex and base there is an obscure suggestion that the stomata lie in four zones, (cf. fig. 11 H), but elsewhere on the leaf, no midrib region can be made out; there may be short lengths in which there does seem to be a non-stomatiferous zone, but they do not last. The details of the stomata are given in the diagnosis and in pl. 1 B and fig. 10 C. They were rather uniform. Some specimens have a rather thick cuticle, but no other regular difference from the rest; I have disregarded this difference and called all specimens the one species.

PODOCARPUS ACICULARIS sp. nov.

Figs. 3 B; 5 A; 8 A, B; 9 A-I; 11 H.

Type specimen (Holotype) University of Tasmania No. 81923 see Fig. 8 B.

Diagnosis: Leaves bilateral, probably spirally borne, normally contracting to an angular petiole, often twisted one pair of flanks over the other. Leaves flat or sometimes probably needle-like in section. Leaves 4-8 mm. long and 0.5-1 mm. wide.

Cuticle about 3 μ thick, amphistomatic, two surfaces only differing very slightly in stomatal density, or not at all; stomata lying well separated in long rows or in groups of two (rarely 3) over entire leaf surface except margins. At apex and base stomata grouped into four more or less definite rows. Cells and cell outlines as for *P. goedei;* 62 μ x 20 μ, in stomatiferous areas cuticle surface always flat. Stomata usually amphicyclic, with distinct terminal encircling cells, but terminal encircling cell sometimes shared between adjacent stomata; where two stomata lying in a group, terminal subsidiary cell often shared, Florin ring distinct, stomatal aperture more or less strongly elongated.

Description. There are only some half a dozen specimens in which the leave of *P. goedei* and *P. acicularis* are attached to their parent shoot. In *P. goedei,* the leaves in the available material come off from opposite sides of the shoot and at, or nearly at, the same level (figs. 8 D-H). In this species it is supposed that the leaves were borne in opposite pairs. On the other hand in *P. acicularis* one clear specimen shows two adjacent leaves pointing over on to one side of the shoot, the base of a third points in the opposite direction and it is at a different level (fig. 8 A). This appearance is like that in *P. dacrydioides* (fig. 1 F) which has spirally borne bilateral juvenile leaves: *P. acicularis* is therefore described as having spirally arranged leaves.

The leaves of both species are described as bilateral because of (1) their insertion (cf. figs. 8 and figs. 1 F, H) and (2) the form of the apex (cf. figs. 8 B, 9 D, E, J, K) and (3) the stomatal distribution in *P. acicularis,* showing four stomatal zones (fig. 11 H). In both species the leaf is usually contracted to an angled petiole, which is sometimes twisted so as to bring one pair of flanks directly over the other. Sometimes the petiole is untwisted (figs. 9 G, I, M-T). This situation finds a parallel, among bilaterally leaved conifers, in *Dacrydium taxoides,* where the petiolate leaf base is twisted, or not, in a very similar way (figs. 1 A-D). From this parallel a suggestion can be made as to the manner in which the leaves were arranged.

In *D. falciforme,* and also in *Podocarpus dacrydioides* and *P. imbricatus,* the leaves are arranged in two rows, though spirally inserted (figs. 1 F, H). However, in *D. taxoides* this is not always so. Some decurrent leaf bases are twisted to bring these leaves into two rows up the shoot, but the orientation of the leaf relative to the shoot itself is unaltered; the leaf is set "edge on" to the shoot. These leaves are not, or only slightly, twisted in the petiole or lower blade (fig. 1 I). Other leaves, however, are not much twisted in the leaf base, but are twisted in the petiole or lower blade (fig. 1 A-4 I). The effect of this is to rotate the leaf so that one pair of flanks faces upwards (i.e. into the sky), and the other paid downwards (i.e. to the ground). Such a leaf is thus "flat on" to the shoot and simulates a normal bifacial leaf.

The similarity in the twisted leaf bases and petioles of the fossils and *D. taxoides* leads to the suggestion that in the fossils also some leaves were born "flat on".

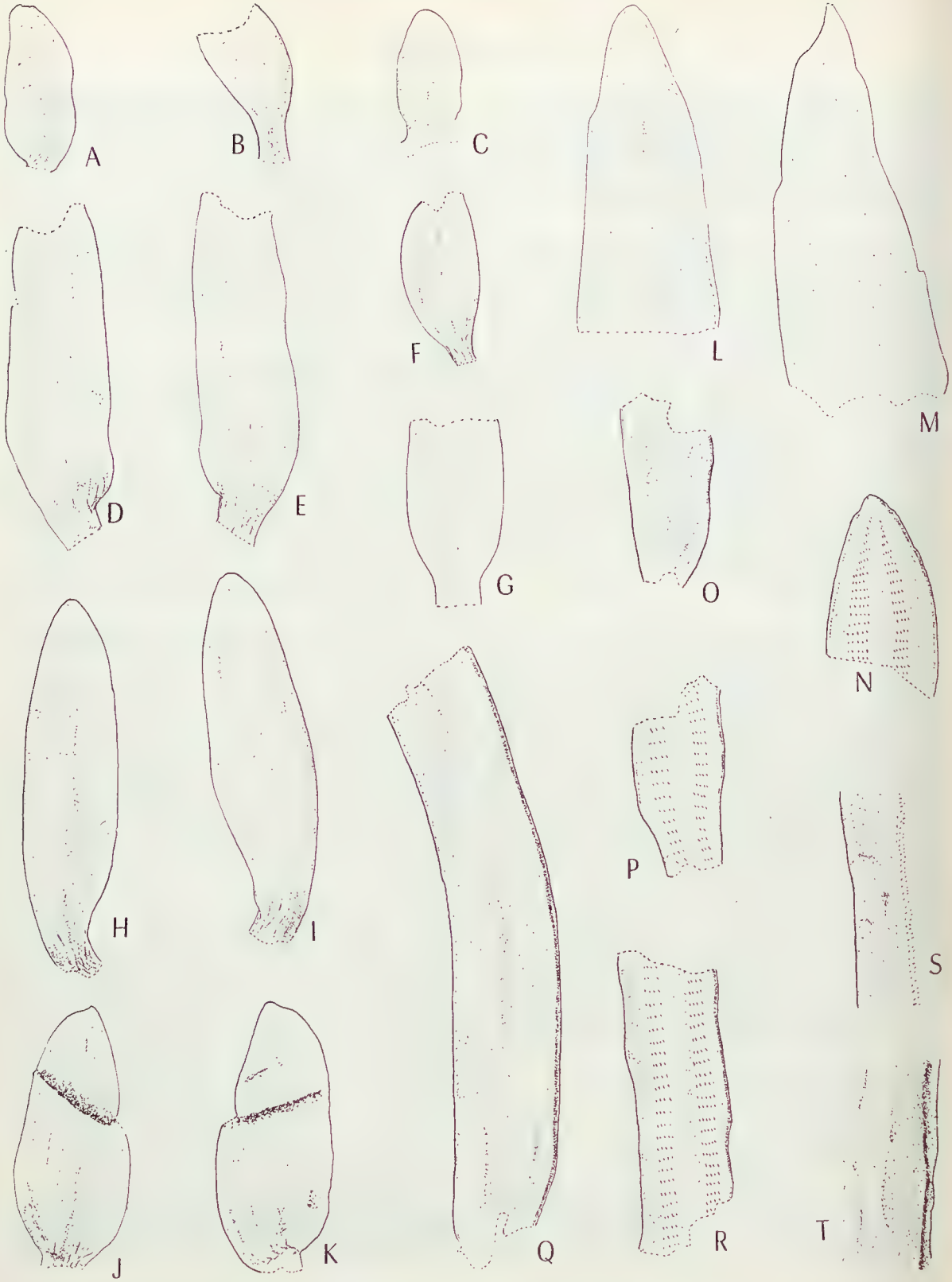


FIG. 6.—*Podocarpus tasmanicus*, A-K; *P. strzeleckianus*, L-T.

A-K: Leaves and leaf bases, small scale-like leaves (A, C, F), twisted bases (D, E, H, I), straight leaf bases (F, G) and small broad leaf (J, K). All x 10. 81905-81907.
L-N: Leaf apex, with shoulders. L, M x 15. 81915. N x 10. 81914.
O, P: A leaf base, Q, R, parts of leaves (note stomatal bands shown by oblique lines) x 10. 81915.
S, T: Scarious margin, both sides of same leaf. (S, lower). x 26. 81912.

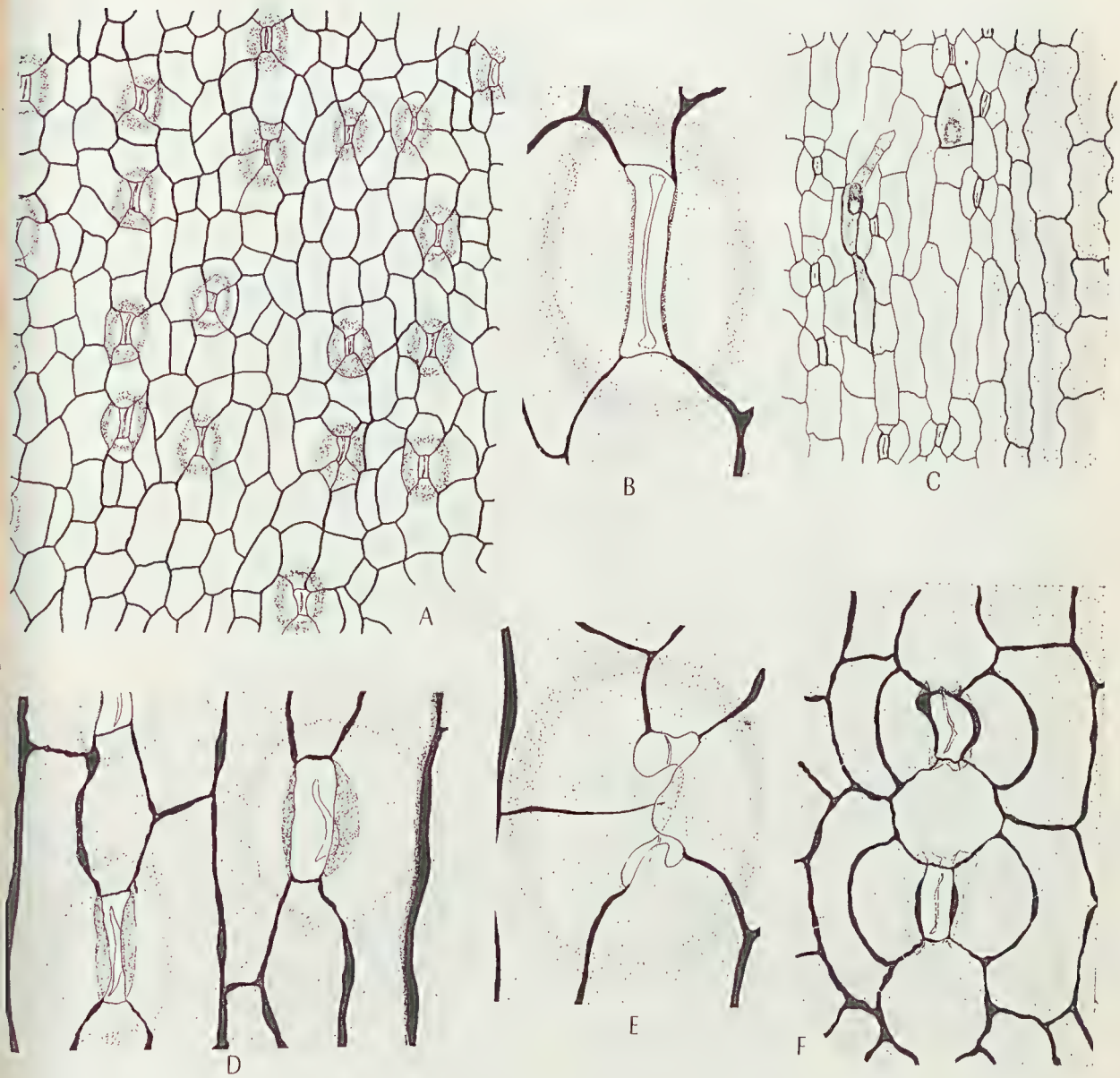


FIG. 7.—*Podocarpus minor*, A; *Microstrobus fitzgeraldii*, B; *M. sommervillae*, D; *M. niphophilus*, E; *Podocarpus setiger*, F; *Coronelia molinae*, C.

A: Upper cuticle, to show arrangement of stomata. Herb. N.S.W. x 330.

B, D, E: Stomata, and surrounding cells and cutin lappets. B, E, Herb. Univ. Tas., D, 81903, x 1,500.

C: Lower cuticle, stomatal rows and margin (right). x 230. 81898.

F: Two stomata and their surrounding cells. x 600. 81922.

A further interesting, perhaps significant, point is that in *D. taxoides* there are stomata over the midrib, as in the fossils, whereas in *D. falciforme*, bearing its leaves edge on, there is a distinct non-stomatiferous zone flanking the midrib.

Some specimens of *P. acicularis* show rather a prominent ridge over the midrib on both sides: these may have been needle-like in cross section. In this species, unlike *P. goidei*, there may be a difference in stomatal numbers on each surface of the leaf, down to about twice as many stomata on one side as the other. The stomatal details are shown in figs. 3 B, 5 A.

Podocarpus goedei and *P. acicularis* are much alike, the differences are in their size (about 10 mm. versus about 6 mm.), in the leaf shape, which may be needle-like in *P. acicularis* and in the form of the stomatal pit. These differences seem to me sufficient to make it convenient to separate the two as distinct species.

Classification. The leaves of *P. goedei* and *P. acicularis* are basically bilateral, and bilateral leaves are taken to indicate the Podocarpaceae. *Acmopyle, Dacrydium taxoides, D. falciforme* and *Podocarpus* section Dacrycarpus show bilateral leaves. *Acmopyle* I rule out for it has a different stomatal distribution, and the subsidiary cells are flat (Florin 1931). The Dacrydiums also differ in stomatal details, for they have long but scattered rows of stomata, adjacent stomata showing a common encircling or subsidiary cell (Florin 1931). However, *D. taxoides* has a strongly contracted leaf base (called here petiolate). Dacrycarpus often shows an uncontracted leaf base (e.g. fig. 1 R), the stomata lie in four zones, one on each flank, not scattered all over the leaf and the subsidiary cells are flat. Thus the two fossils do not fall easily into any living group with bilateral leaves.

On the other hand they show considerable resemblance to *Podocarpus minor* (section Polypodiopsis). The leaves are thick, with an obscure, or even invisible midrib; the stomata are scattered in short rows all over both surfaces of the leaf (except a marginal band) sometimes in nearly equal numbers on both surfaces (*P. minor* usually has more stomata below, however); the stomatal rows are long, but somewhat vague, and within a row there may be groups of 2 to 5 closely set stomata (figs 5 A, 7 A, 10 C): and the number, arrangement and form of the subsidiary cells is similar, especially in that both fossils and *P. minor* have the Florin ring. (Figs. 10 C, 4).

The difference is that the leaves are bilateral in the fossils and bifacial (approaching equifacial) in *P. minor*.

The fossils are placed in *Podocarpus*, but they will not fit into an existing section.

The evolution of the Polypodiopsis sort of foliage.

It has been concluded that both *P. goedei* and *P. acicularis* bore bilateral leaves, some of which were twisted so that one pair of flanks pointed upwards, the other pair down. It has also been deduced that while the leaf arrangement in *P. acicularis* may have been spiral, in *P. goedei* the leaves may have been opposite and decussate (fig. 8 D). Also, a similarity has been noticed between these fossils and *P. minor*.

P. minor (fig. 1 J) has opposite and decussate more or less equifacial leaves arranged so that in each pair the adaxial surface faces the axis. It seems to me that a series of forms can be traced through the fossils to *P. minor*. That is from a shoot with bilateral, spirally inserted leaves, some borne "flat on". (*P. acicularis*); to a shoot with opposite and decussate, but still bilateral, leaves (*P. goedei*); to, finally, more or less equifacial leaves (*P. minor*). That is, the Polypodiopsis sort of leaf insertion and form can be derived, with the fossils as models, from a bilateral leaf.

A difficulty, however, is that the leaves of *P. minor* are not twisted at the base, but on the suggestion just made, one would perhaps expect them to be twisted. Further developments in Sect. Polypodiopsis are to increase the torsion in the internodes and also twisting the leaf blade as in *P. rospigliosii* or *P. vitiensis* (see Florin 1931: 192-194, also fig. 1 G, Gray 1962). Since species of Polypodiopsis resembling *P. rospigliosii* and *P. vitiensis* were already evolved in the lower Tertiary, they are *P. araucoensis* and *P. brownei, P. goedei* and *P. aciculosus* are most unlikely to represent evolutionary sequence.

Section Afrocarpus also has equifacial leaves, lying more or less in two rows up the shoot, but the leaves of *P. falcatus* and *P. gracilior* (at any rate) in this section are spirally inserted, and twisted in the leaf base, essentially as in *Taxus* or *Sequoia* (fig. 1 K). I think it is unlikely that Polypodiopsis and Afrocarpus are especially close to one another (Gray 1953). Section Nageia also has decussate leaves, but these are multiveined.

Family Podocarpaceae

Genus **MICROSTROBUS** Garden and Johnston

MICROSTROBUS SOMMERVILLAE sp. nov.

Pl. 2 B; Figs. 4 E, G, H; 5 C, D; 7 D.

Type (Holotype): University of Tasmania No. 31900, see Fig. 4 G.

Diagnosis. Ultimate leafy shoots 1-2 mm. in diameter bearing spirally arranged leaves, probably about 5 leaves in one turn of the spiral. Leaves 2-3 mm. long, 1.5-2 mm. wide at widest, decurrent, and showing cutinised upper surface about 1.5 mm. long. Leaves pointed, or acuminate, diverging from shoot at angle of 10°-20°, widest part near base of leaf. Abaxial leaf surface strongly keeled, adaxial leaf surface somewhat keeled. Depth of leaf (when compressed laterally) 1-1.5 mm.

Cuticle epistomatic, stomata borne in two zones, separated proximally by a triangular non-stomatiferous zone, but coalescing near leaf apex. Cells of under surface similar all over, in rows, rectangular or forming parallelograms, about 60 μ x 15 μ. Cell outlines much pierced by holes, between holes swelling out laterally to give sinuous appearance to outline. Cells of upper surface forming the margins and non-stomatiferous zone similar to cells of under surface, but oulines more delicate and less sinuous; 70 μ x 12 μ. Stomata lying in rows 4-6 stomata high, the zones 4-6 stomatal rows wide, one or two stomatal rows lying at apical end of the non-stomatiferous zone. Stomata sharing

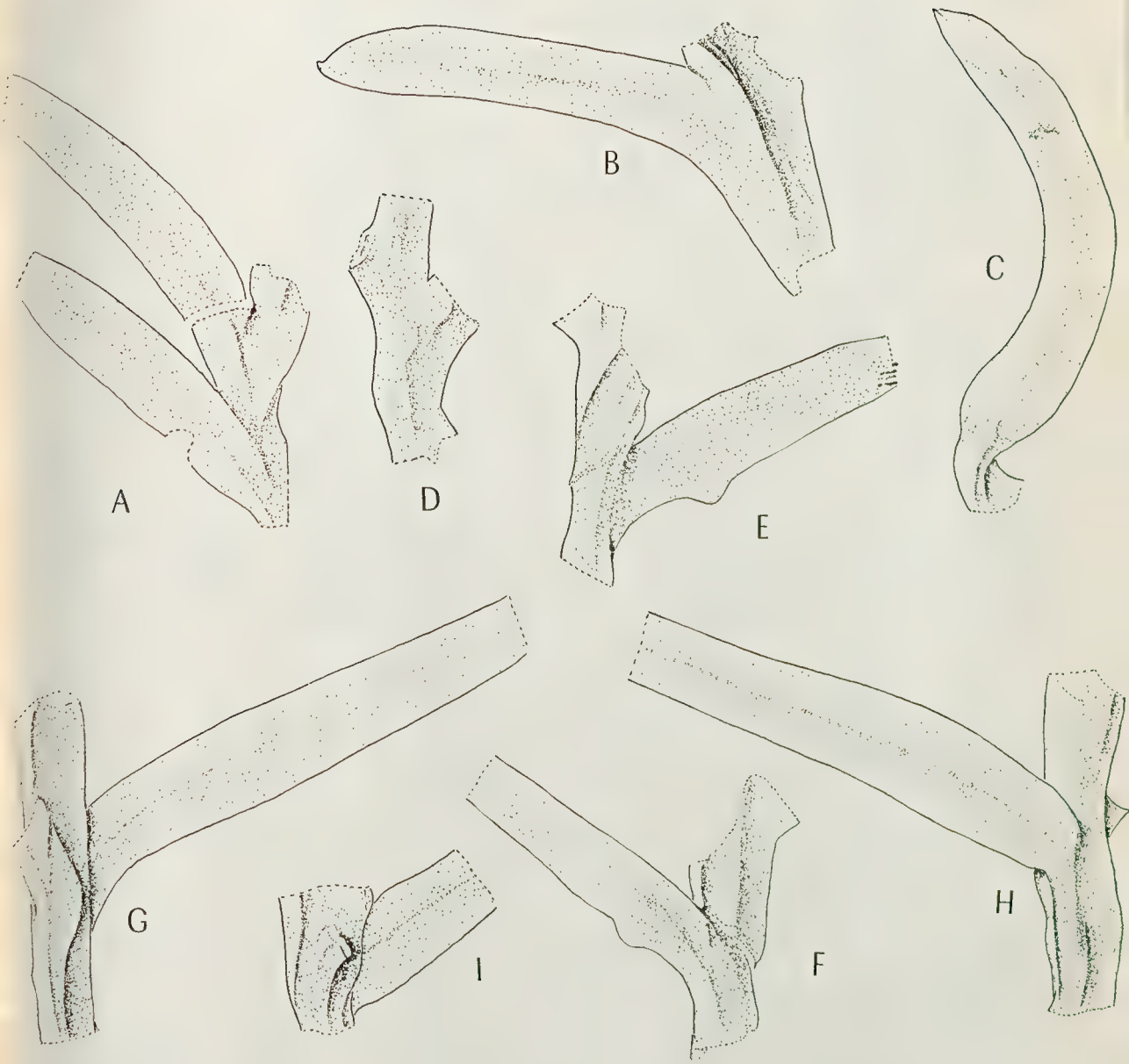


FIG. 8.—*Podocarpus acicularis*, A, B; *P. geodei*, C-I.

A: Shoot, two adjacent leaves pointing the same way, and a broken leaf base to right. x 15. 81923.
B: Complete (small) leaf, untwisted at base. x 15. 81923.
C: Falcate leaf with twisted base. x 10. 81929.
D: Leaf bases, pointing in opposite directions, and nearly on same level. x 10. 81931.
E, F: Two opposite leaves, nearly at the same level. x 10. 81932.
G, H, I: Opposite and decussate leaves. x 10. 81931.

FIG. 9.—*Podocarpus acicularis, A-I;* 81927 a, b. *P. goedei,* J-T. 81928 a-c, 81930.

A, G, F: Twisted leaf bases. x 15.
C, I: Untwisted leaf bases. x 15.
B, D, E, H, J, K, L: Leaves with apices, or leaf apices. B, D, E, H x 15; J, K, L x 10.
M, N, O, P: Two bases with twisted bases, both sides drawn. x 10.
Q, R: Leaf with long angled petiole. x 10.
S, T: Leaf bases, untwisted. x 10.

terminal subsidiary cells, lateral subsidiary cells of adjacent stomata touching, or sometimes one subsidiary cell shared between two adjacent stomata. Usually two lateral subsidiary cells, rarely three or four. Stomatal pit overhung by upward projection borne on all the subsidiary cells, aperture of the pit usually rectangular, about 14 μ x 5 μ, rarely partly occluded by the upward projection, or by cutin extension (lappett) of it; projection and lappetts (if present) not very large. Junction of ad, and abaxial leaf surfaces marked by cutinised processes. Processes finger-like more or less independent of one another near leaf base, and lying in one or two rows, becoming concrescent and forming single crest towards leaf apex.

Discussion and Classification. This species is represented only by half a dozen or so small shoot fragments, extensive enough, however to show that the leaves are spirally borne, not opposite (figs. 4 E, G, H). Though decurrent the leaves are free over most of their length, to judge from the extent of cutinisation on the upper leaf surface; and on the hand specimens show a strong keel on the under side, and some sign of a keel on the upper also (figs. 4 G, H). This is confirmed from the cuticle, which on the upper leaf surface, at the edges of the non-stomatiferous zone is a little folded (fig. 5 C). The leaf shape is somewhat variable, one specimen (fig. 4 H) showing longer leaves than usual, the leaves also being slightly falcate. The cuticle, however, is similar in all the material seen (Pl. 2 B, figs. 5 C, D; 7 D).

The fossils show small, almost scale like leaves, epistomatic and spirally borne. This narrows the field for comparison very greatly. According to Florin (1931, 1958) several genera, e.g. *Microcachrys* (Podocarpaceae), *Callitris*, some *Juniperus* species and others among the Cupressaceae show, or may show, scale-like epistomatic leaves, but these genera have opposite, and opposite and decussate, or whorled leaves. This leaves *Microstrobus* (*Athrotaxis selaginoides* differs in its much larger leaves and in its stomata). In addition to the above points, the form and cuticle of the fossil agrees extremely well with *Microstrobus*.

Microstrobus has two species *M. niphophilus* (earlier known as *Pherosphaera hookeriana*) and *M. fitzgeraldii*. *M. sommervillae* comes nearly exactly intermediate between them. In gross form it is more like *M. fitzgeraldii* (figs. 4 F, I), in stomatal distribution, cell outlines and marginal fringe, very close to *M. niphophilus* (Florin 1931, pl. 17, fig. 1, pl. 26, fig. 7, also pl. 2 B fig. 5 D), but in detailed construction of the stomatal pit again it recalls *M. fitzgeraldii* (figs. 7 B, D and Florin 1931, pl. 18, fig. 8). Incidentally, in the fairly abundant material of the Tasmanian endemic *M. niphophilus* the stomatal pit is rather often more occluded (fig. 7 C) than is suggested by Florin's figure (1931, pl. 18, fig. 8). The stomata of *M. sommervillae* are rather more open than either living species, and the finger-like processes forming the marginal fringe more distinct. A further point is that the projection over the stomatal pit (Florin 1931, fig. 68 A, B) is smaller (or rather, less distinctly seen) in the cuticle of *M. sommervillae* than in either living species (figs. 7 B, D, E).

The specific name is suggested in acknowledgement of much help received from Miss Janet Sommerville, University of Tasmania.

As far as I know, *Microstrobus* has not been found fossil before. The genus evidently was clearly recognisable, at least its foliage was, in the early Tertiary. A further point of great interest is that it is found fossil in one of the only two places where is now grows. In this *Microstrobus* contrasts with *Microcachrys*, now a Tasmanian monotypic endemic, but judging from pollen grains, widespread in Tasmania and elsewhere in the past (see p. 19).

? PODOCARPACEAE.

Coronelia molinae Florin

Pl. 2 C. Figs. 3 G, H; 4 D, 5 F, 7 C.

1940 *Coronelia molinae* Florin, 20-22: Pl. 3, Figs. 3-10; Pl. 4, Figs. 1-8; Pl. 5, Figs. 1-4. Description of Type from Chile.

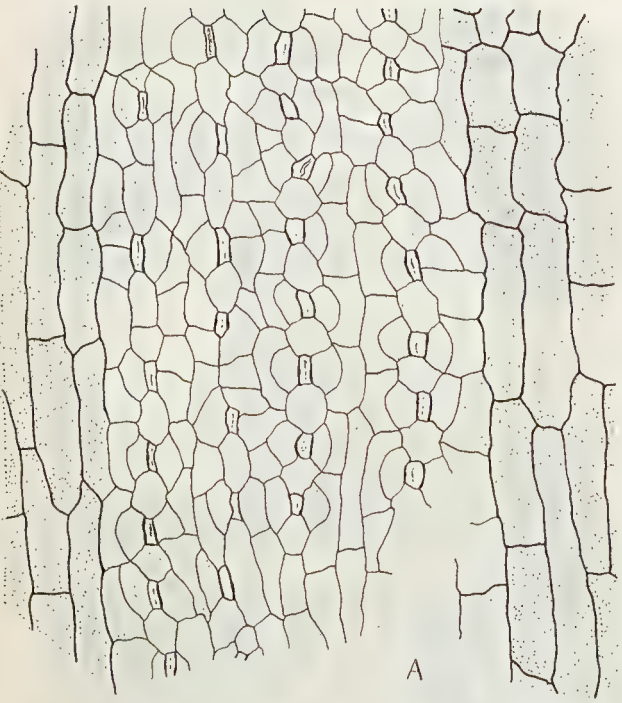
Description and discussion. The material consists of four leaves, but is identified because it agrees almost exactly with the type, and with nothing else.

One complete leaf is 12 mm. long and 2.5 wide at the widest, another is 3 mm. wide at the widest (versus 15-16 mm. x 3 mm. given by Florin): and two specimens show the base, sharply contracted to a short petiole; and from the widest point, very near the base, the leaf tapers gradually till very near the apex, when it contracts suddenly to an acuminate point, (Pl. 2 C, and fig. 4 D cf. Florin 1940 pl. 3 fig. 10). The minute marginal teeth are seen in pl. 2 C.

The leaves are hypostomatic, with the stomata lying in two bands separated by a rather indefinite (and sometimes indiscernible) non-stomatiferous zone over the midrib, which does not extend to the leaf apex (pl. 2 C). The Chilean material had a non-stomatiferous zone over the midrib, but in the figures (e.g. pl. 3 figs. 3, 6) it is seen to be indefinite, as in the Tasmanian leaves. The papillae on the encircling and subsidiary cells are most variable, usually faint (fig. 3 G) sometimes invisible, but sometimes strong (fig. 3 H), stomata with strong papillae tending to appear in groups; the papillae on one leaf show a gradation from separate papillae to a distinct Florin ring (figs. 3 H, 5 F). In the Chilean material the papillae are stronger, but still distinctly variable and only seen sometimes (Florin 1940 pl. 4 figs. 3, 4, 8). In the papillae found a little away from the stomatal apparatus agreement is complete (fig. 3 H cf. Florin pl. 3 fig. 5).

The stomatal details are shown in figs. 3 G, H; the stomata lying rather separate from one another in sparse rows within the stomatal zones (fig. 7 C) and the stomata themselves are dicyclic with (usually) two lateral subsidiary cells, but sometimes three or four (fig. 5 F). In these respects agreement is complete between Florin's material and mine (cf. pl. 3, figs. 5, 6; pl. 4, figs. 3, 4).

Perhaps the most prominent feature of the cuticle is the hairs, which lie in the stomatal zones, and all point more or less in the same



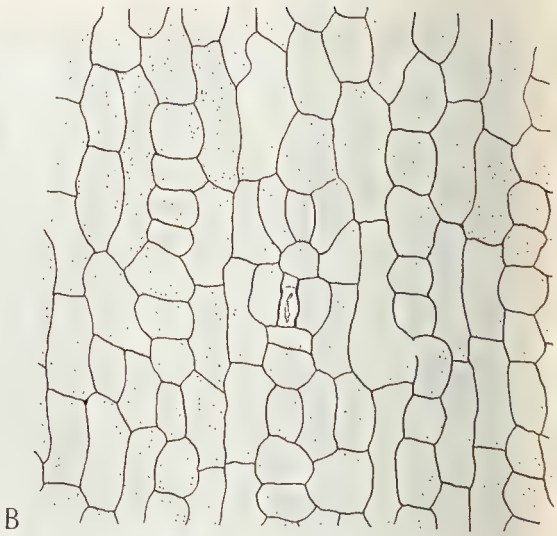


FIG. 10.—*Podocarpus setiger*, A, B; *P. gocdei*, C; *P. minor*, D, E.

A: Cuticle from one flank, compact stomatal zone. x 230.
B: Cuticle from another flank, a stoma, and (presumably) incompletely developed stomata above and below it. x 230. A and B, 81922.
C: Stomata, and surrounding cells. x 600. 81933.
D, E: Stomata in surface view and transverse section. Herb. N.S.W. x 600.

direction (pl. 2 C). These arise from a single cell, or more often the terminal cell of a short row and are multicellular, or unicellular when small, (fig. 3 G, H). Thus far they agree with those shown by Florin (pl. 3, figs. 5, 6, 9: pl. 4, fig. 5, 7). The difference lies in their form. In my material the larger hairs are mostly broken off (figs. 5 F, 7 C), the smaller ones are pointed (fig. 3 H): in Florin's material, however, though most figured examples are broken off, the end cell in some is swollen (e.g. pl. 3, fig. 8). This is the only definite difference between the Tasmanian and Chilean leaves.

I am inclined to explain it away. If the terminal cell swelled up at maturity it might become weak and be broken off before preservation. One example (pl. 3, fig. 5, to left) in Florin's material appears to be pointed, and it is a small hair. The multicellular hairs were stated by Florin to be an unusual feature: to some extent, however, they can be matched (when small) by the *marginal* hairs of *Podocarpus setiger* (P. 9 figs. 5 B, E) which are, however, normally unicellular, though whether this similarity is of significance I doubt. The larger papillae are hollow (fig. A H), and may look like very small hairs. Possibly the two organs are ultimately of the same nature.

The material adds very little to our knowledge of the affinities of *Coronelia;* its main interest is stratigraphic and geographical. As noted, the Tasmanian and Chilean leaves correspond at nearly every point, and I think they almost certainly belong to the same species. This is important, for it suggests a lower Tertiary age for the Buckland flora, though not indubitably, since the range of *Coronelia* is unknown. It also adds another small point of similarity between the Chilean and Australian Tertiary floras.

GENERAL DISCUSSION

It is known, mainly from pollen studies, that in the early Tertiary there was a forest flora, in which the Podocarpaceae were prominent, extending over New Zealand, southern Australia, Chile and southwards to the Antarctic. (e.g. Cookson 1953, Cookson and Pike 1953, 1953a, 1954, Couper 1960, 1960a, Selling 1950, Florin 1940, 1963). The present species fall into this flora. Sections Dacrycarpus and Polypodiopsis were already known to occur in Tasmania, (neither are now found in Australia). Eu-podocarpus Section D, Stachycarpus (not now in Tasmania, *P. ladei* in N. E. Queensland) and *Microstrobos* are new. It is surprising not to have found *Dacrydium,* for this genus (in its sections B and C) is also known to have occurred in Tasmania in the early Tertiary, as did *Phyllocladus* and *Microcachrys.* They will doubtless turn up in time.

Florin (1963) has argued strongly that the present sections and sub-sections of the Podocarpaceae, especially of *Podocarpus,* originated well to the South of the present chief density of sections and species in the New Caledonia, Fiji, Indonesian region. In this he differs from Bucholtz and Gray (1948) who ignored the fossil record. Gray (1962), however, has since partly accepted Florin's views.

The present material supports Florin with two examples of foliage which, as it is interpreted, lie somewhat intermediate between sections or subsections, but which are found well to the South of the present range of the most similar species. *P. tasmanicus* (p. 7) is believed to lie close to *P. ladei* (sub-section Idioblastus) now found in the Atherton region of Queensland. But it can also be compared with *P. ferrugineus* (Euprumnopitys) of New Zealand. The two species *P. goedei* and *P. acicularis* (pp. 11-13) are believed to show features recalling both Polypodiopsis (New Caledonia, New Guinea, Fiji, Equador) and Dacrycarpus (New Zealand, also New Guinea to Burma).

With the exception of *P. geodei* and *P. acicularis* the species described here fall easily into sections or genera. This supports the view, also derived from pollen studies, that by the Tertiary the genera, usually sections and sometimes subsections, of the Podocarpaceae were already in existence. The species, however, do not seem to have been evolved.

While the present distribution of some groups (e.g. the Araucariaceae Cookson and Duigan 1951) can rather easily be interpreted in terms of a simple retreat northwards under the influence of increasing cold, leading to the Pleistocene glaciations others have stayed put. Examples are Eupodocarpus sub-section D, Stachycarpus, subsection Euprumnopitys, Dacrycarpus, and also *Microstrobos, Phyllocladus* and *Dacrydium* of groups B and C. Simple refrigeration will not explain their distribution. It seems likely here that desiccation was equally important, but I hope to elaborate on this elsewhere.

ACKNOWLEDGMENTS

I am very grateful indeed to the following, wh[o] have helped me with material of living conife[rs] for comparison: Dr. R. H. Anderson, Sydney; D[r.] N. T. Burbridge, Canberra: Mrs. N. Gray, Decatu[r], Georgia, U.S.A.; Dr. J. B. Hair, D.S.I.R., Ne[w] Zealand; Professor R. Howard, Arnold Arboretum; Mr. F. W. James, British Museum, (Natural History); Professor J. Rylands, Kirstenbosch, South Africa; Dr. B. Slade, Otago University, New Zealand; Mr. G. Watkins, Forestry Department, Fiji; Mr. J. H. Willis, Melbourne. I must also thank Professor H. N. Barber, F.R.S., University of New South Wales, and Dr. W. D. Jackson, University of Tasmania, for help and criticism during the course of this work.

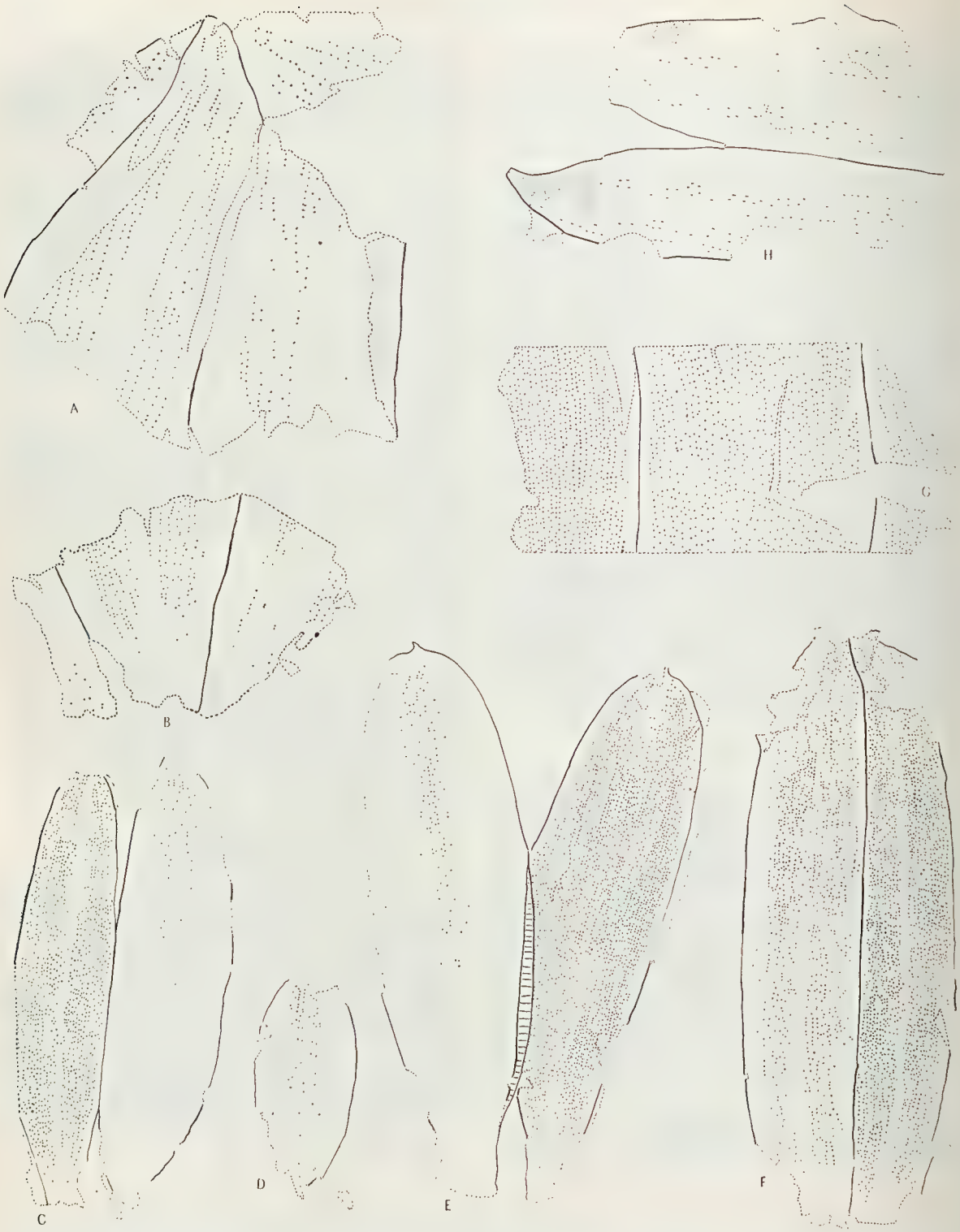


FIG 11.—*Podocarpus tasmanidus*, A, B. *P. ferrugineus*, C, D; *P. ferruginoides*, E; *P. ladei*, F; *P. minor*, G; *P. acicularis*, H.
A, B: Apex and base of a leaf, showing stomatal distribution. x 12. 81910.
C-F: Stomatal distribution in members of Sect. Stachycarpus, all x 8.
K: Part of a leaf, upper cuticle in centre. x 8.
H: Apex showing form and four rows of stomata, one on each flank. x 12. 81920.

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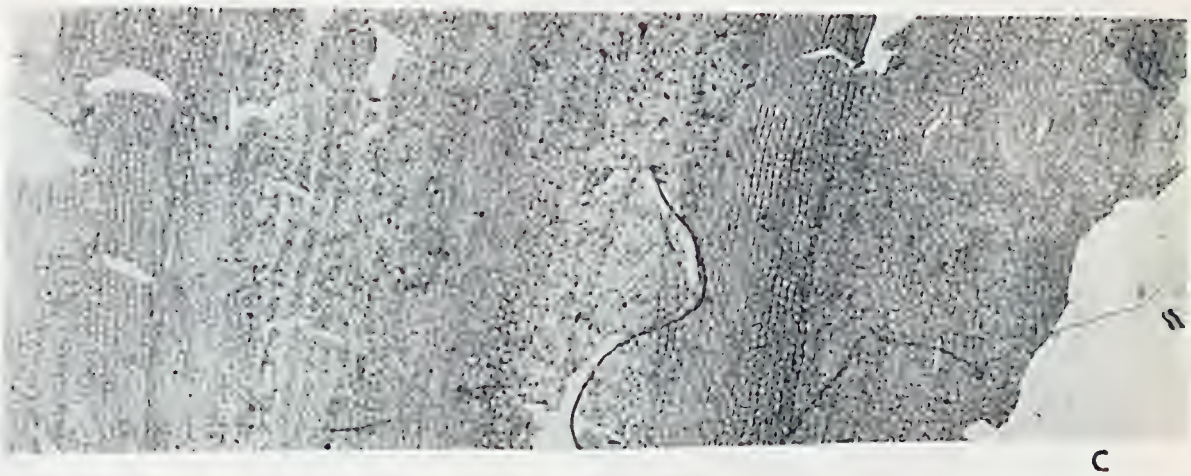

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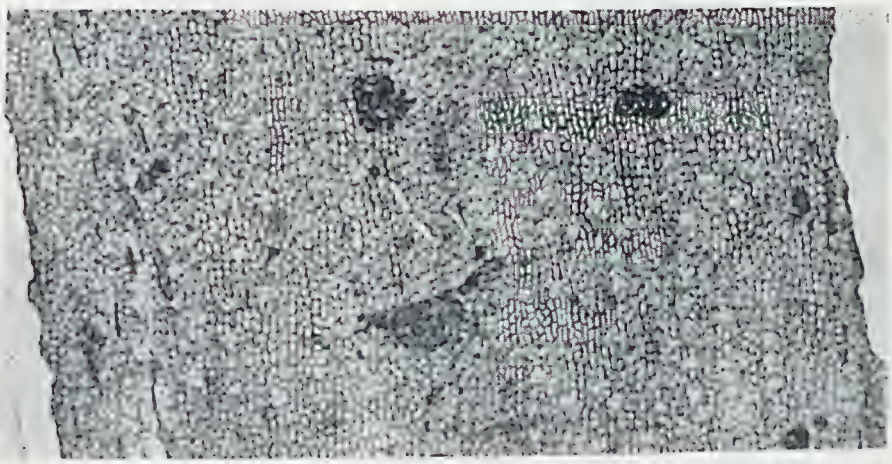
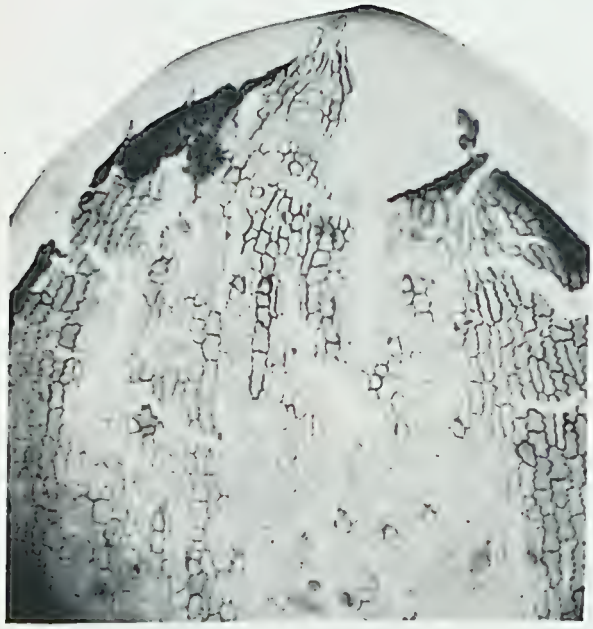


B

A

Plate 1.—*Podocarpus tasmanicus*, A; *P. goedei*, B; *P. strzeleckianus*, C. All x 50.
Portions of the leaves to show margins, midrib region and stomatal distribution. 81908, 81934, 81917.



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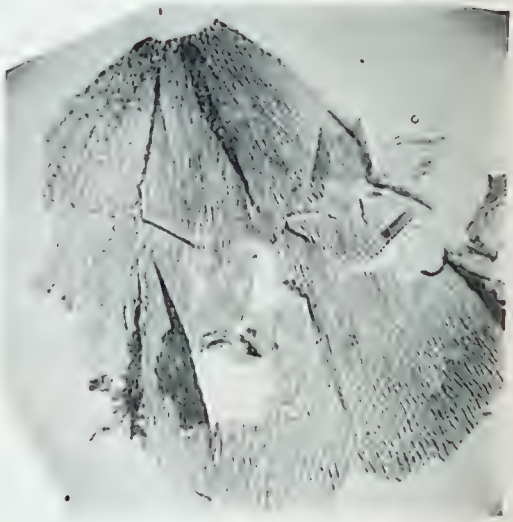

B

A

Plate 2.—*Podocarpus setiger, A; Microstrobus sommervillae,* B; *Coronelia molinae,* C. All x 50.

A: Portions of both pairs of flanks, showing stomatal rows. 81920.

B: Both leaf surfaces, showing stomatal distribution and marginal wing. 81904.

C: Apex of the lower cuticle of a leaf. 81898.

Papers and Proceedings of the Royal Society of Tasmania, Volume 99.

NOTES ON TASMANIAN PINES
II. ATHROTAXIS FROM THE LOWER TERTIARY

By

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(With 2 text figures)

ABSTRACT

A species of *Athrotaxis* is described from the Lower Tertiary of the Buckland basin. With hesitation it is identified with *A. ungeri* (Halle) Florin from the Lower Cretaceous of Patagonia. The ecology of *Athrotaxis* is discussed.

INTRODUCTION

In the first of these notes some podocarps from a Lower Tertiary locality near Buckland were described. The same locality has yielded a species of *Athrotaxis*. *Athrotaxis* in the past was widespread in the Southern Hemisphere, though it is now endemic to Tasmania; its fossil record in Tasmania, however, is very uncertain.

I am indebted for help and criticism to Dr. W. M. Curtis and Dr. W. D. Jackson, University of Tasmania.

DESCRIPTION OF THE MATERIAL

Family Taxodiaceae.

Genus **ATHROTAXIS** D. Don.

Athrotaxis ungeri (Halle) Florin.

Figs. 1 and 2.

1913 *Athrotaxites ungeri* Halle, pp. 40-44; pl. 2 figs. 11-17, pl. 3 figs. 13-20 ? 21, pl. 4 fig. 22, pl. 5 figs. 10-13, Lower Cretaceous, Patagonia.

1940 *Athrotaxis ungeri Halle;* Florin, p. 35. Change of name.

1963 *Athrotaxis ungeri* Halle; Florin, p. 202. Note only.

Locality: Tea Tree Rivulet, Buckland, Tasmania.

Diagnosis, emended. Shoots 2-4 mm. in diameter, with rounded apex, showing closely packed, spirally arranged scale leaves; usually one complete leaf and parts of two others seen on one side of the (now flattened) shoot. Leaves about 3 mm. long and 2.5 mm. wide (extremes, 4 x 2.75 mm. and 2.0 x 1.5 mm., at apex). Widest part about 0.75 mm. from leaf base, leaf contracted slightly towards leaf base and contracting above to a more or less acute apex. Compressed sideways, leaves about 1.0 mm. thick. Lower (abaxial) surface rounded, not keeled. Upper (adaxial) surface flat, consisting of a portion over the midrib about 0.75 mm. long and two narrow parts tapering from apex towards widest part of the leaf.

Cuticle on lower surface 5μ or more thick, on upper about 1.5μ. Leaf amphistomatic, stomata lying in two zones of indefinite outline on the lower leaf surface, and in two zones set close to leaf edge on the upper leaf surface; zones separated by triangular area over midrib, not reaching leaf apex. Stomata mostly orientated more or less longitudinally but no regularity of arrangement apparent. Epidermal cells away from stomata in indistinct longitudinal rows. Leaf margin ornamented along its whole length with a wing of long finger-like cells, joined lateraly over most of their length; wing up to 0.1 mm. wide at leaf apex.

Epidermal cells on lower leaf surface more or less equidemsional, or slightly wider than long, about 40μ x 35μ, outlines thick, up to 7μ, straight, with rather indistinct edges, penetrating far down anticlinal cell walls, outlines sometimes pierced by holes. On upper leaf surface cells more or less rectangular, 38μ x 20μ outlines thin. No epidermal papillae or other ornament present. Stomata normally monocyclic, rarely incompletely dicyclic, subsidiary cells more or less equidimensional, 4-8, mostly 5 or 6 round each stomatal pit, set in a circle, scarcely or not divisible into lateral and terminal members. Stomatal pit overhung by collar of cutin arising from periclinal surface of subsidiary cells (not wall of stomatal pit), collar up to 7μ wide. Stomatal pit more or less round or slightly elongated parallel with the long axis of the pore, guard cells feebly cutinised, even around pore.

Marginal wing composed of single layer of cells, uniting proximally with both upper and lower leaf surfaces, composed of often transversly divided cells having finger-like ends.

DESCRIPTION AND CLASSIFICATION

The material consists of short lengths of leafy shoots and is somewhat local in the Tea Tree material. None of the shoots show branching, but all show the leaf arrangement, and one, an apex (Figs. 1A, B, C-E). The leaf length was, however, obtained from isolated leaves, since on the shoots the leaf bases are covered up; the extent of the upper leaf surface was obtained from the cuticle (Fig. 1F). No veins were visible. The leaf showed no sign of a definite keel, in this resembling *living A. cupressoides* (Fig. 1H) the marked keel seen in some figures (e.g. Florin 1931, pl. 11 fig. 8) appears as the specimen is dried and is thus an artefact.

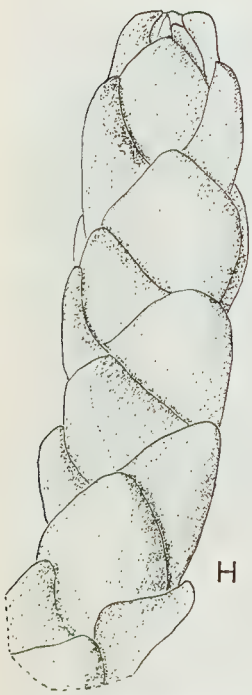
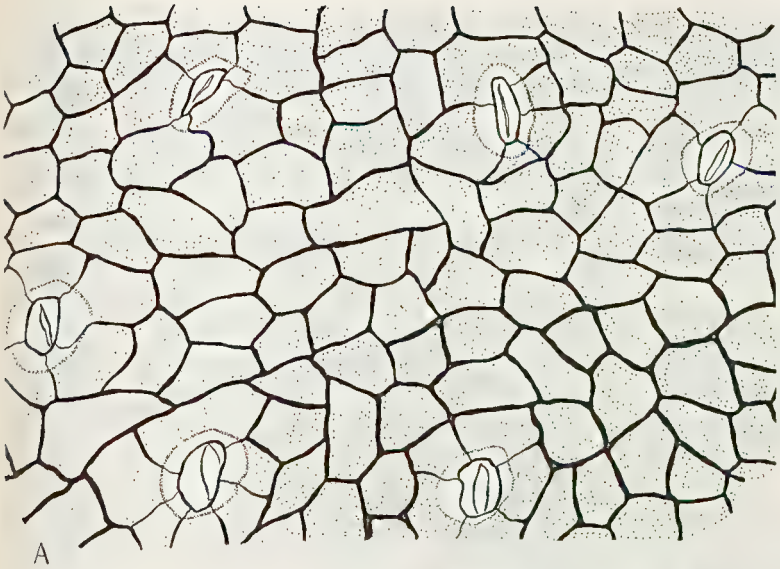
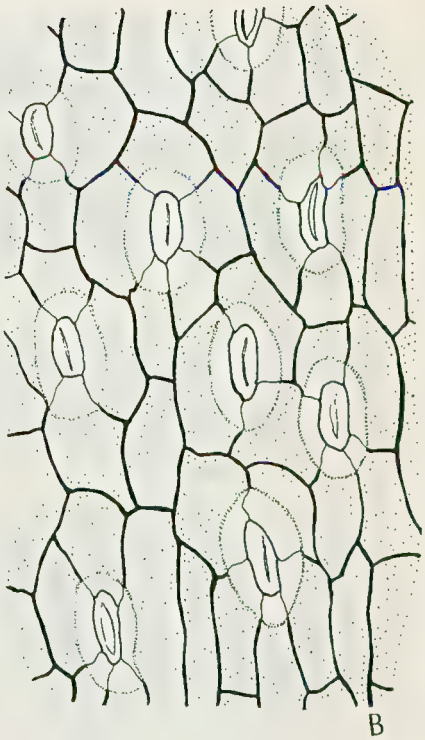


FIG. 1.—A-G: *Athrotaxis ungeri* and H, *A. cupressoides*. A-E: Fragments of shoots, showing leaf form and appearance of marginal wing. x 10. 81893-81895. F: A leaf macerated whole. Area of upper cuticle close stipple; stomata on upper surface fine lines, on lower heavy lines; marginal wing cross-lined. x 26. 81897. G: Leaf apex macerated, showing cells of marginal wing, cells and stomata of upper leaf surface, and some cells of lower leaf surface (heavy lines to centre). x 135. 81897. H: A shoot, to show leaf form. Draw from living material, *note* absence of a distinct keel. x 10.





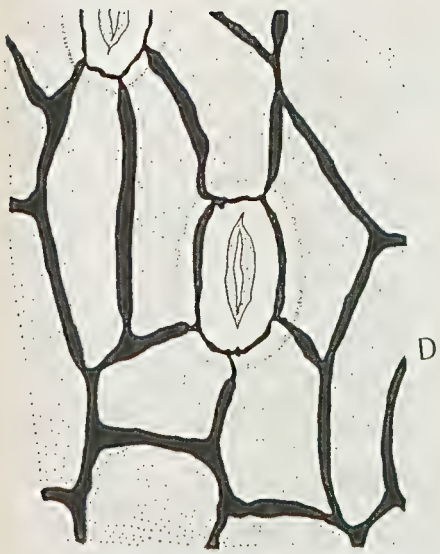


FIG. 2.—A-C: *Athrotaxis ungeri* and D, E, *A. laxifolia*. A, B: Cuticle from lower and upper leaf surfaces respectively, to show stomatal arrangement and cell outlines. x 350. 81896. C: A stoma, lower leaf surface, showing collar round stomatal pit, and subsidiary cells. x 600. 81896. D: A stoma, lower leaf surface, in surface view. x 600. E: A transverse section through a stoma, showing collar round stomatal pit, and subsidiary cells. x 600.

The cuticle was rather brittle, despite its thickness. Its chief features, and the marginal wing, are shown in Figs. 1G, 2A-C. A very important feature is the collar round the stomatal pit. This appears as a nearly colourless rim, often in the fossil caved into the stomatal pit, but showing the outlines of the subsidiary cells (Fig. 2C). Sections of living species show that this rim is composed of a set of papillae on the subsidiary cells, fused to form a collar (Fig. 2E and see Florin 1931: 365-369 for full description of the genus). The rim, i.e. collar, is larger in the fossil than in the living species, however.

The combination of features points towards *Athrotaxis*, and (it appears) no other genus: of special importance is the leaf arrangement, the lack of regular orientation of the stomata, and irregular arrangement of the subsidiary cells, the (mostly) monocyclic stomatal apparatus, and the collar round the stomatal pit, an especially useful feature (Florin 1931, 1958).

In the gross form the fossil is most like *A cupressoides*, being distinguished from the other two by its small leaves, closely appressed to the stem (e.g. Fig. 1A, B). It is also distinguished from *A. selaginoides* by being amphi—not epistomatic. The cuticle is, however, nearest to that of *A. laxifolia* from which it is distinguished by (1) showing, proportionately, more stomata on the lower surface, and (2) the large marginal wing. *A. ungeri* is distinguished from *A. cupressoides* on its cuticle, as follows: it has a much wider collar round the stomatal pit, a larger marginal fringe to the leaf, no papillae, even at the leaf base, and very narrow non-stomatiferous margins on the upper leaf surface.

Curtis (1956, p. 6) points out that *A. laxifolia* is in many ways intermediate between the other two species, and discusses the possibility that it may be a hybrid. This idea she finally rejects. The recognition of *A. ungeri* supports her view. In stomatal details *A. laxifolia* is not intermediate between *A. selaginoides* and *A. cupressoides*, but points towards an extinct species, different from all the living species.

Florin (1960) discusses the fossil record of *Athrotaxis* and concludes that all Northern Hemishpere records are suspect or wrong. Following this view, only the southern records of shoots are here compared: these are as follows:—

(1) *Athrotaxis ungeri* (Halle) Florin (see Halle 1913, pp. 40-44). The shoots of this species showed closely appressed leaves, rhombic in outline, about 3 mm. long and 2 mm. wide. The leaves appear to have been thick, their edges are described as straight (see especially pl. 2 figs. 15, 17). In this they are most like *A. cupressoides*, as Halle points out. I can point to no definite difference between Halle's specimens and mine. It may be that the leaves of Halle's specimens are slightly smaller than those of mine; it looks also as if their margins are straighter. Unluckily, however, Halle's material showed no cuticle, and the figures show no sign of a marginal fringe. Halle's specimens come from the Lower Cretaceous of Patagonia (Rio Fossiles).

With much hesitation I identify the Tasmanian specimens as conspecific with the Patagonian ones. In absence of cuticle comparision is extremely incomplete. Gross form alone (as noted) will not satisfactorily separate the Tasmanian *A. ungeri* and *A. cupressoides*: but the cuticle does at once. The difference in age is also a reason for hesitation, but is not of itself ground for making a new species.

(2) *A. australis* Bose (1955: pp. 385-386). This species consists of poorly preserved shoot impressions, probably differing from *A. ungeri* in having larger, more acute and less closely appressed leaves. However the specimen shown in pl. 2 figs. 16 and 17, also text-fig. 1a is decidedly like my material.

(3) *A. novae-zealandiae* (Ettingshausen) Florin (see Ettingshausen 1891: p. 254). Two small shoots of this species are figured both showing longer, less appressed and more acute leaves than *A. ungeri*.

(4) The only Tasmanian fossil records of *Athrotaxis* are given by Johnston (1888). *A. ? tamarensis* could be a shoot of *A. ungeri* but is regarded as inderminable. A cone *Sequoia* (later *Athrotaxis*) *tasmanica* (Johnston) Florin is also mentioned. I prefer to regard this specimen as indeterminable.

DISCUSSION

Athrotaxis has been recorded from the Lower Cretaceous of Patagonia, and at various levels in the lower Tertiary from New Zealand, Queensland and New South Wales. Assuming (as seems probable) that *Athrotaxis* has existed more or less continuously in Tasmania since the Lower Tertiary (for the last 50 to 60 million years) its present restriction to Tasmania represents a contraction into a part of its earlier range, not a spread into a new area. It recalls *Microcachrys*, which seems to have behaved in a similar way (Couper 1960).

There is, however, a strong suggestion that the ecology of at least the Tasmanian Tertiary species (and I suspect those from elsewhere also) was different from that of the living species. The Tertiary *A. ungeri* is found along with tropical or sub-tropical pines, such as *Podocarpus* sects. Polypodiopsis, Dacrycarpus and Stachycarpus. Further, in the early Tertiary Tasmania, with Eastern Australia in general was a low-lying peneplain with a warm moist climate (Gill in Spry and Banks 1962). It looks as if the *Athrotaxis* was then a warm temperature rain forest tree. It is, of course, possible that *Athrotaxis* then, like *Phyllocladus* now, had both highland and lowland species: but there is no evidence of this yet. The living species of *Athrotaxis* are highland trees, though still, it is to be noted, confined to high rainfall areas.

Athrotaxis is, probably, not unique in showing an apparent change of ecology as between the Tertiary and the present, *Microcachrys* is most likely similar. There is, therefore, at least the hope that if we could discover the factors that have confined *Athrotaxis* to the Tasmanian austral montane flora, we could apply the same arguments to other groups in that flora.

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Papers and Proceedings of the Royal Society of Tasmania, Volume 99.

PLEISTOCENE DRIFT IN THE MERSEY AND FORTH VALLEYS—PROBABILITY OF TWO GLACIAL STAGES

By

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(With six text figures and two plates.)

ABSTRACT

Deposits of Pleistocene drift in the Mersey and Forth Valleys are described. The deposits in the Mersey Valley are referable to one glacial stage, but those in the Forth Valley are thought to indicate two glacial stages.

INTRODUCTION

This paper describes deposits of Pleistocene drift in the Mersey and Forth Valleys adjacent to the north-western boundary of the Central Plateau in Tasmania. The deposits were examined during investigations for the Mersey-Forth Power Scheme. Those found in the Forth Valley are of special interest because they are thought to indicate two glacial stages during the Pleistocene in this part of Tasmania.

Mather (1956), and Jennings and Ahmad (1957) examined the Central Plateau bordering the Mersey Valley. The latter authors recognised only one glaciation, an ice cap glaciation, during which the ice moved away from a major ice divide that ran SW-NE through the Walls of Jerusalem.

Spry (1958) made a reconnaissance of the Mersey-Forth-Arm area and deduced that the ice spilled over the edge of the plateau in many places during the ice cap phase. It filled the existing Mersey and Forth Valleys and tributary valleys with ice almost 2000 feet thick, and covered Maggs Mount and Borradaile Plains. He concluded that the ice cap phase was followed by a less severe valley glacier phase, but that it was not possible to decide whether the first and second phases were separated by an interglacial period, or whether the ice cap merely shrank leaving valley glaciers that were active for a considerable period with minor advances and recessions.

Jennings and Banks (1958) and Davies (1962) reviewed all the evidence of Pleistocene glaciation in Tasmania and reached the conclusion that it was referable to one glacial stage. These authors abandoned the scheme developed by Lewis (summary, 1945) of three full glaciations—Malana (ice cap), Yolande (valley glacier) and Margaret (cirque glacier)—constituting a series of declining glacial intensity.

MERSEY VALLEY DEPOSITS

Spry (1958) and Jennings (1963) described U shaped valleys with truncated spurs, hanging valleys, smoothed quartzite outcrops and roches moutonnées in the Mersey-Little Fisher-Arm area. Ford (1960) described till, erratics, moraines and lineations in the Little Fisher Valley, and Macleod et al (1961) briefly described till in the Upper Mersey Valley.

The distribution of drift in this part of the Mersey Valley system is shown on Figure 1. All the deposits examined are referable to one glacial stage.

Valley Slope Deposits

The western slope of Clumner Bluff is covered with deposits of mixed origin. The material is thought to include ice sheet spillover, ice contact deposits, valley glacier deposits and periglacial solifluction material. The deposits have been examined by pits along the Mersey-Fish and Mersey-Little Fisher Roads. These were dug to a maximum depth of 18 feet.

Typically the pits contain an upper solifluction layer up to 4 feet deep, underlain by a layer up to 6 feet deep of poorly bedded gravels and boulders, which dip towards the valley at about 15°. This layer is underlain by gravelly to bouldery till lacking bedding. An example of the bedded layer, probably an ice contact deposit, is shown on Plate I, Figure 1. A typical particle size distribution curve of material of less than 6 inches diameter of the till from the Mersey-Fish road is shown on Figure 2.

Cuttings along the Arm Valley Road expose bouldery till (Plate 1, Figure 2) within which lie some 20 feet of varves. The varves occur about 300 feet above the floor of the Mersey Valley and are well consolidated and tough. Till is again exposed at a higher level, but its relationship to the varves is not clear. It appears that a lake existed in the Arm Valley, probably dammed by deposits from the main Mersey Glacier.

Valley Floor Deposits

Ground moraine and fluvioglacial material extends as far downstream as Parangana Damsite ½ mile below the Fisher River Junction. Immediately below the damsite the nature of the valley changes; the straight, broad valley becomes a narrow, winding valley with interlocking spurs. No drift was found at Martha Creek Damsite 1½ miles downstream of Parangana Damsite and 70 feet lower in altitude. The deposits were examined at Rowallan and Parangana Damsites.

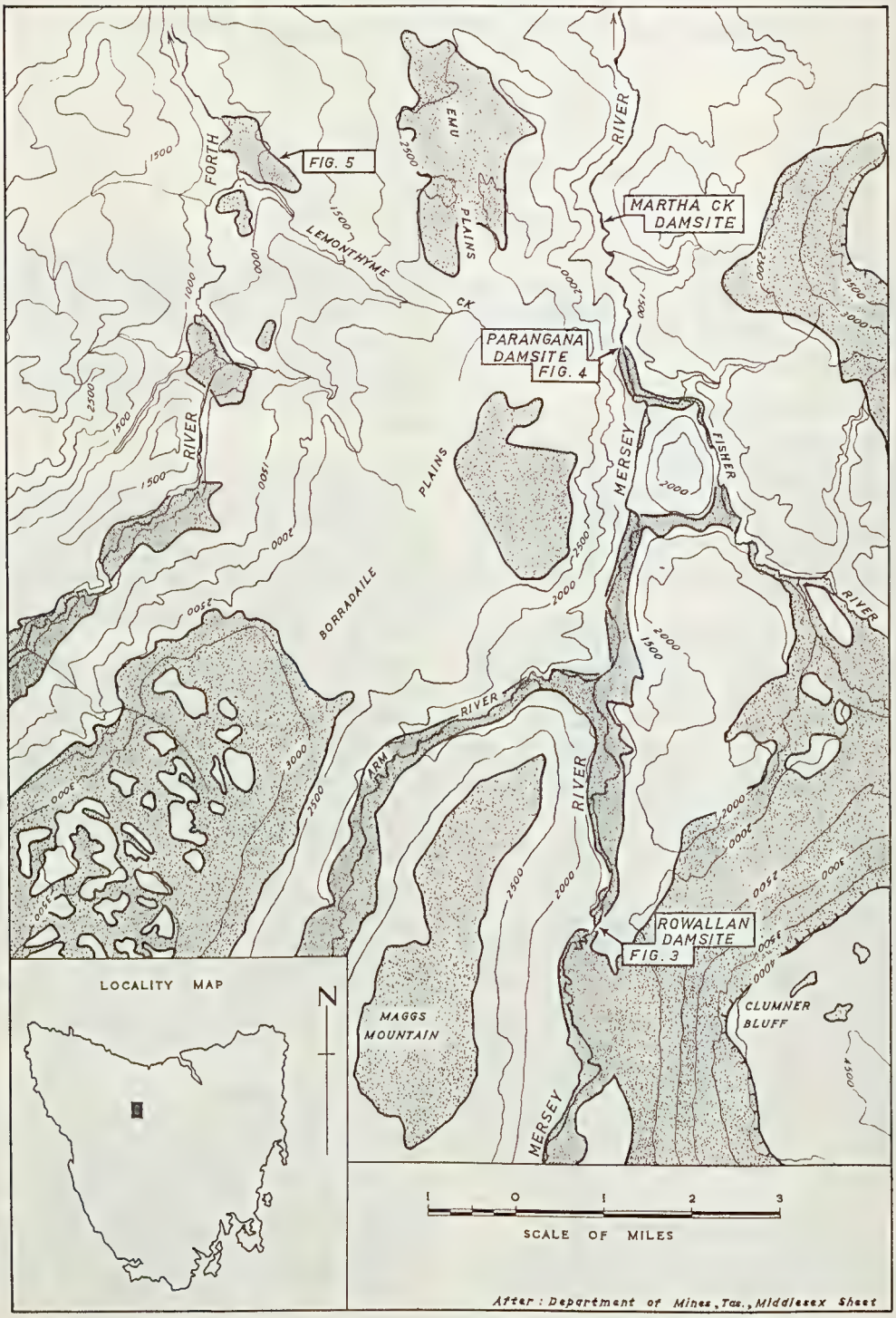

FIG. 1.—Distribution of Drift in the Middle Mersey and Forth Valley systems.

Rowallan Damsite:

Rowallan damsite (Figure 3) is situated at the downstream end of a flat drift plain known as Walters Marsh and Howells Plains. It is 6 miles long and ½ mile wide.

At the damsite the Mersey, a superimposed river, flows transverse to the structural trend through Precambrian Howell Group metamorphics. It is constricted to a 10 foot wide channel against the eastern wall of the valley by a ridge, an overturned anticline in quartzite and schist, which forms a local base level protecting the drift plain from erosion. The ridge is separated from the western wall of the valley by a 400 foot wide buried channel of the Mersey River, which is filled with drift. The channel has an asymetrical profile and the drift extends to a maximum depth of 133 feet, The base of the deposit is at an altitude of 1397 feet, which is 90 feet below the present river bed.

The greater part of the drift deposit is till, composed of an unstratified, heterogeneous mixture of boulders, cobbles, pebbles, sand, silt and clay. The coarse material is sub-rounded to sub-angular and ranges up to 6 feet in diameter. The greater part of the deposit was derived from dolerite with quartzite and schist contributing only minor amounts. Weathering extends only a few feet into the deposit, and the fresh matrix is bluish-grey in colour. Drill hole 5746 has shown the presence of one fluvioglacial sand lens or channel 6 feet deep filled with fine yellowish-brown dolerite and quartz sand. Nevertheless water tests in drill holes 5747 and 5748 have shown the drift to be practically water tight. Most tests yielded leakage rates of less than 1 gallon per minute at 100 pounds per square inch pressure.

Spry (1958) carried out a mechanical and petrological analysis of material from near the damsite. He found it to be tough, well consolidated and lacking bedding. Comparatively speaking it was not friable and was tougher than most Tasmanian Permian and Triassic sediments. His histogram and cumulative curve indicate the material to be poorly sorted and to contain a considerable spread of sizes. 80% of the material was in the pebble, granule and sand grades with silt and clay grades comprising only about 20%. Spry found the larger particles were dolerite with a little quartzite, the sand was fine-grained dolerite, quartz, pyroxene and feldspar, and the silt was quartz, pyroxene and plagioclase. The particles were fresh and unweathered and of low roundness and sphericity. He concluded that although the degree of sorting was not unlike that of some river gravels, the composition, particularly its content of fresh, sand-silt size pyroxene and plagioclase, is quite different.

Ford (1964) carried out an X-ray analysis of the matrix of the fresh till. He found it to consist of fine-grained quartz and a mica type mineral. No clay mineral of the kaolinite or montmorillonite groups was found.

Parangana Damsite:

Parangana Damsite (Figure 4) is located 7 miles downstream from Rowallan Damsite. Here the Mersey River flows transverse to the structural trend through vertically to near vertically foliated Precambrian Fisher Group quartzites, schists, phyllites and slates.

The site has been glacierized rather than glaciated, but it has a broad upper profile and a narrow central channel. Up to 40 feet of talus overlies drift that has a maximum thickness of 50 feet in the channel section. The material rests on channel filling at an altitude of 1070 feet. The depth of the channel is not known, but drill hole 5768 indicates it to be in excess of 120 feet below the base of the drift. The drift has been investigated by drilling and an adit.

The material visible along the river bank and in the adit is a bouldery till similar to that encountered at Rowallan Damsite. It consists of a well consolidated, unstratified, heterogeneous mixture of boulders, cobbles, pebbles, sand, silt and clay. Seventy per cent of the deposit is in the pebble and larger size ranges, and this material is coated with clay, silt and sand. In contrast with the Rowallan deposit the fine material is weathered yellowish-brown at a depth of 75 feet below the surface. Some properties of the matrix are listed in Table I.

TABLE I.

Properties of Till Matrix Parangana Damsite.

Sieve Analysis—	
	83% passed No. 4 (5 mm.)
	60% passed No. 30 (0.6 mm.)
	36% passed No. 200 (0.07 mm.)
	6% passed 0.02 mm.
Liquid Limit	42
Plastic Limit	32
Plasticity Index	10
Linear Shrinkage	4
Specific Gravity	2.77

Most of the deposit has been derived from dolerite with basalt, quartzite and schist contributing minor amounts. The boulders of dolerite, basalt and schist are sub-rounded to rounded and range up to 3 feet diameter, whereas the boulders of quartzite are angular and range up to 10 feet diameter. The quartzite and basalt boulders are probably locally derived scree, but the dolerite boulders have been transported from the Central Plateau. The high proportion of sub-rounded to rounded material is notable. The explanation probably lies in a combination of weathering in the source area, distance of transport, and reworking during advances and retreats of the glaciers.

No striated or faceted boulders have been found. This is in accordance with the experience of Jennings and Ahmad (1957), who were unable to find any such minor erosional features on the plateau. It is presumably the result of chemical weathering to which dolerite is susceptible.

Deposits at the Fisher River Junction show faint gravel and sand bedding dipping upstream at up to 15°. In view of the situation at the junction of two glaciers it seem likely that the deposits were laid down under glaciolacustrine conditions. E. Derbyshire (personal communication), however, has suggested that the upstream dip may indicate layering produced within the ice and thus deposi-

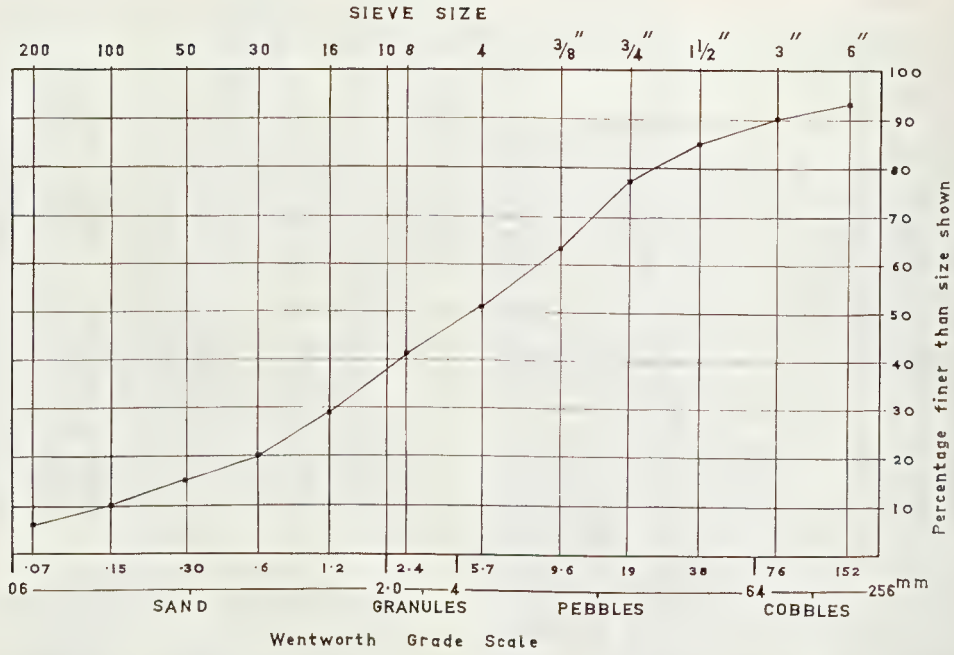

FIG. 2.—Particle Size Distribution Curve of material of less than 6" diameter from the till from the Mersey-Fish Road.

tion under glacial conditions. He (1963) observed similar features in the Lake St. Clair morainal tract, and has suggested that the bedded cores of these moraines represent englacial debris with which the downwasting ice was heavily charged; the moving ice behind depositing the basal till along the planes of shear with the inert ice in front and below.

FORTH VALLEY DEPOSITS

Spry (1958) and Jennings (1963) briefly described varves occurring along the Forth Valley between Lemonthyme Creek and Lorinna, and noted the presence of a terminal moraine at Lorinna. The deposits at the Forth-Lemonthyme Creek Junction were examined by drill holes and pits along the Lemonthyme Penstock Line (Figures 1 and 5). The underlying bedrock is Precambrian Dove Group schist.

The drift sequence (Figure 6 and Plate 2) consists of a basal tillite[1], interbedded tillite, varves, mudstones and siltstones, gravelly to bouldery till, and carbonaceous clays, sands and silts. These are in part overlain by periglacial solifluction material.

The base of the tillite lies at an altitude of 750 feet. The tillite is gravelly to bouldery, generally hard to well cemented, light to dark grey, without bedding or sorting of constituents. Approximately 70% of the constituents are in the granule to boulder ranges, and the material is angular to subrounded. It is composed of dolerite (Jurassic), basalt (Tertiary), and quartzite and schist (Precambrian) fragments. Some physical properties of the tillite are listed in Table II.

[1] Tillite—used in the rock sense as a consolidated and indurated till, but without the age connotation applied by Penck that the rock formed during glacial epochs anterior to the Pleistocene (Rice, 1955).

TABLE II.

Properties of Tillite—Lemonthyme Creek.

Sample	Dry Density lbs./cu.ft.	Wet Density lbs./cu.ft.	Moisture Content %	Compressive Strength lbs./sq.in.	Indirect Tensile Strength lbs./sq.in.
1	158.6	162.8	2.63	1827	
2	167.7	171.2	2.12	2568	353 (average)

The tillite forms a blanket over the valley floor, and the deposit has a known width of 3000 feet. A maximum thickness of 80 feet was obtained in drill hole 5803.

The interbedded tillite, varves, mudstones and siltstones appear to have been deposited in a channel about 2000 feet wide near the present channel of the River Forth. A maximum thickness of 93 feet was obtained in drill hole 5808. The rocks are well compacted, but loosely cemented and friable. Except occasionally, the sediments are not a series of graded beds, and Derbyshire (personal communication) considers them inadequate for a worthwhile estimation of time. They are weakly varved and the varved portions are generally gross, averaging 2 to 4 inches.

The interbedded tillite, varves, mudstones and siltstones are overlain by a gravelly to bouldery till at the western end of the penstock line, and by periglacial solifluction material at the eastern end.

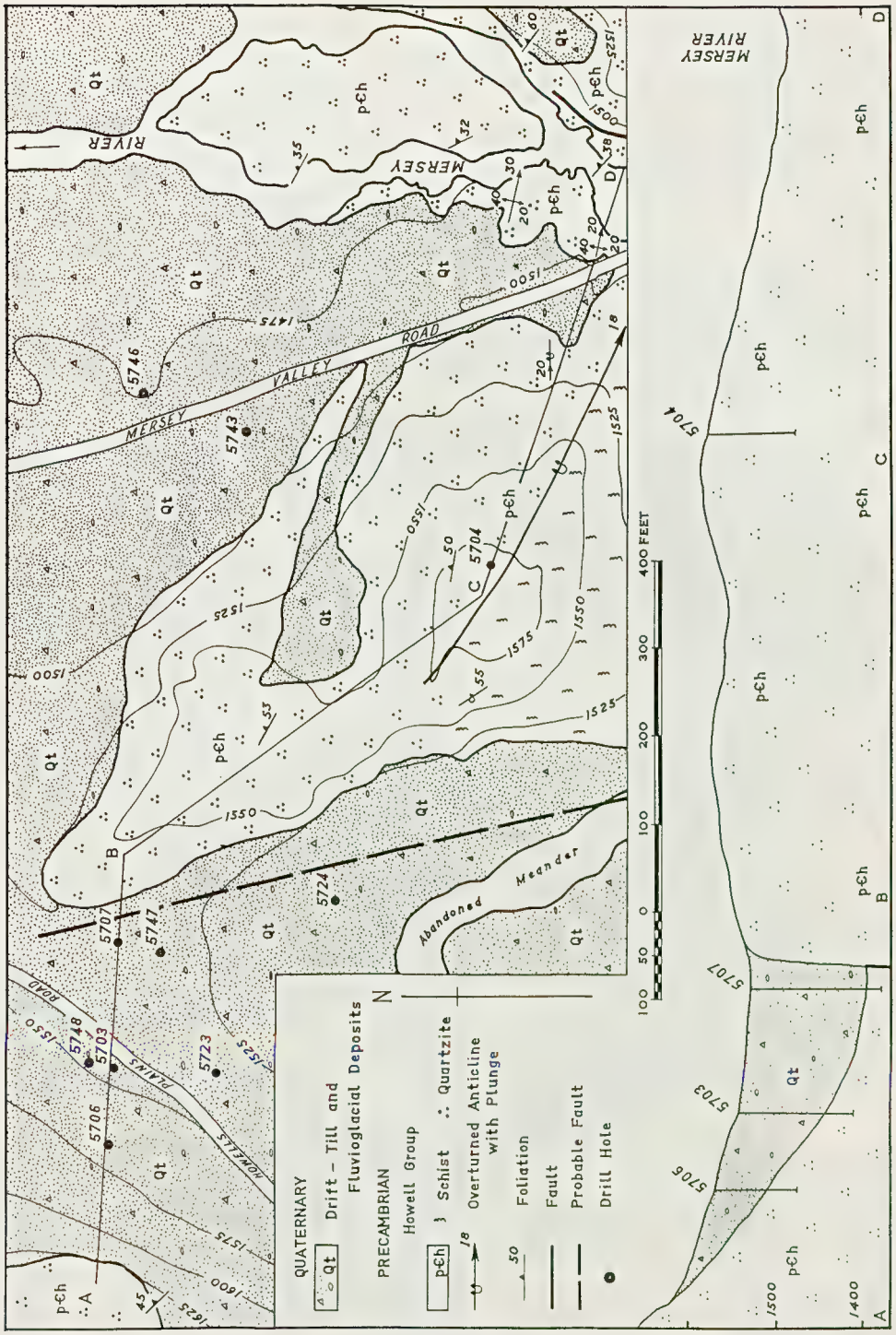

FIG. 3.—Rowallan Damsite.

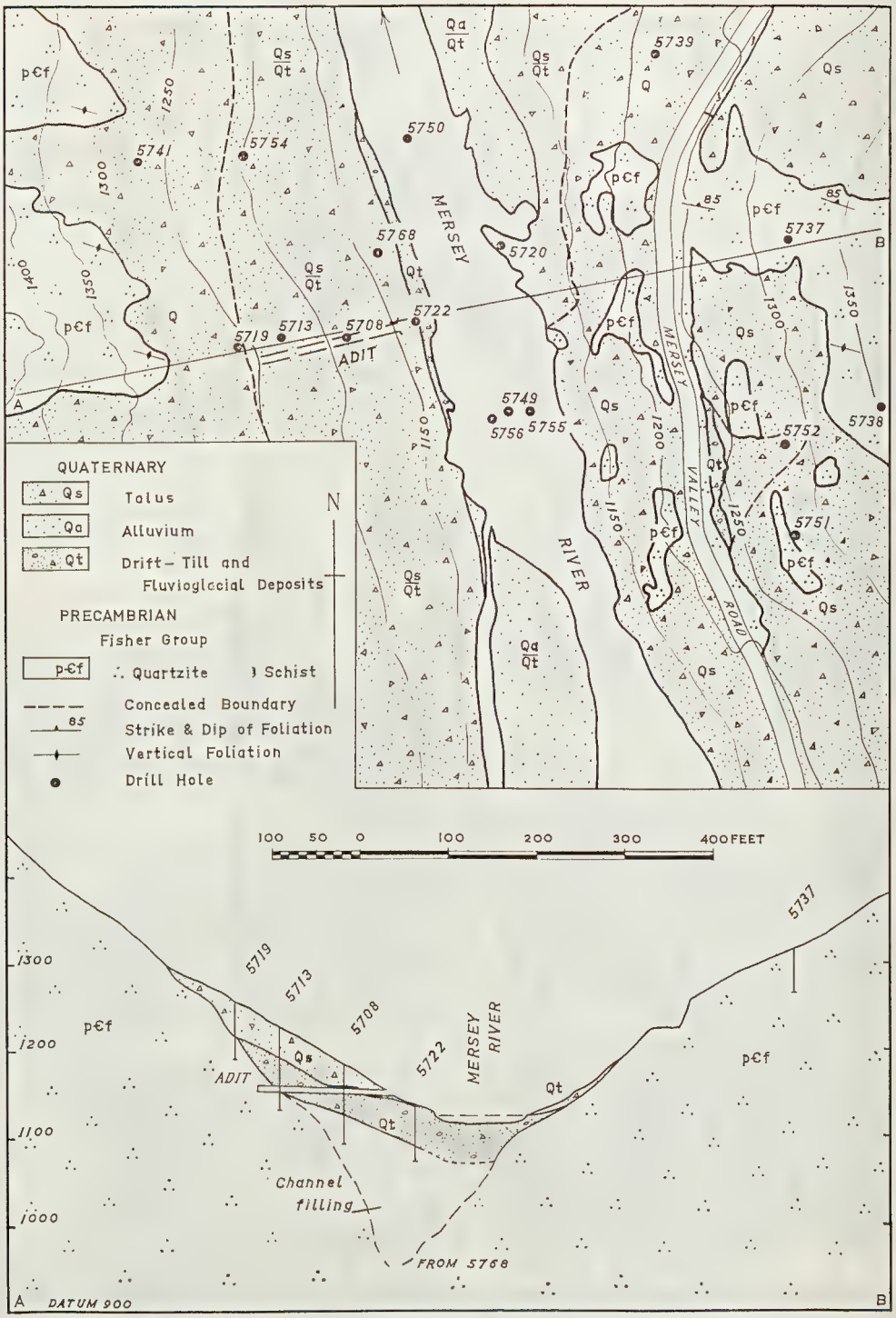

FIG. 4.—Parangana Damsite.

The blanket of gravelly to bouldery till has a known width of 2500 feet and a maximum thickness of 45 feet in drill hole 5802. It consists of an unconsolidated, unstratified, heterogeneous mixture of boulders, cobbles, pebbles, sand, silt and clay. The proportion of coarse material varies from 20% to 70% and consists of sub-rounded fragments of dolerite and basalt, and angular fragments of quartzite and schist. The surface matrix is a soft, yellowish-brown clay of low to high plasticity.

Periglacial solifluction material appears to be the basal deposit in an old channel of Lemonthyme Creek at the eastern edge of the drift deposit. This channel has been traced by drilling and refraction seismic survey for a distance of 2500 feet. The solifluction material is a soft to firm, dark-greenish-grey clay containing up to 10% of angular quartzite pebbles and granules and sub-rounded dolerite and basalt pebbles and cobbles.

Drill hole 5833 encountered 9 feet of solifluction material, but the bulk of the channel is filled with compacted but uncemented black to dark grey laminated carbonaceous clays, silts and sands containing a few pebbly horizons. The beds have a dip of 3°.

Spry (1964a) made a petrographic study of the clays, sands, and silts from drill hole 5825. He found that all the pebbles were derived from Precambrian quartzites and schists; no basalt or dolerite pebbles were found. He observed mud flakes in sandy layers and sandy layers in the clays, which are characteristic of Pleistocene lacustrine sediments. Graded bedding suggested varves, and the strong swelling of many clay-rich samples on immersion in water was similar to the behaviour of the varves from the Arm Valley. Specimens were extremely poor in heavy minerals. No olivine or pyroxene that could be attributed to Tertiary basalt were found, nor pyroxene derived from Jurassic dolerite. Minerals originating in the Precambrian rocks included tourmaline (common), biotite, rutile (very rare); no garnet was found. The most abundant material was black, crusty and ferruginous and appeared to be haematite. Spry concluded that the sediments were Pleistocene glaciolacustrine in origin. The age was later established by drill hole 5833 which indicated that the beds rest on till and tillite. M. R. Banks of the University of Tasmania is examining the abundant carbonaceous material. A maximum thickness of 110 feet of these sediments was found in drill hole 5825, and the beds were overlain by up to 65 feet of solifluction material.

Ferruginous conglomerate and siliceous quartz conglomerate, resembling Ordovician Roland Conglomerate, occur along the southern margin of the buried channel. Spry (1964b) examined specimens petrographically but was unable to make a positive identification. He concluded that they were probably Tertiary greybillies. G. Rawlings (personal communication) has found greybilly at the base of the basalt on the western slopes of Gads Hill, some 400 feet above the channel, and on Emu Plains. It would appear that the channel was in existence in Tertiary time.

The tillite, varves, mudstones and siltstones are thought to have been deposited during the first glacial stage. Drill hole 5808 recorded three tillite layers and two varve-mudstone-siltstone layers, indicating three glacial advances when material was deposited as till and two retreats when glaciolacustrine conditions prevailed. The third retreat may not have left distinguishable deposits, or these may have been reworked during the glacial advance of the second glacial stage and redeposited as till.

The second glacial stage is thought to have commenced with a glacial advance that deposited the blanket of gravelly to bouldery till. It appears that this advance blocked the Lemonthyme Valley and created a lake in which the clays, silts and sands were deposited. The final phase of channel filling was completed by periglacial solifluction.

The probability of two glacial stages is inferred from the marked lithification of the tillite as compared with the overlying till. The marked difference in degree of lithification suggests an age difference, though variations in the weight of overlying ice may have been a major factor. Spry's (1958) observations on the glaciation of Maggs Mount and Borradaile Plains, and Rawlings' (personal communication) observation of till on Emu Plains, indicate a thickness of ice of the order of 2000 feet in the valley areas during the ice cap phase, when presumably the tillite was deposited. This thickness would be considerably less during the decline of glacial activity.

The difference in degree of lithification is reflected in the seismic velocities obtained in the various materials. Velocities were obtained up to 18,000 feet per second in the tillite, up to 5,000 feet per second in the gravelly to bouldery till, up to 7,000 feet per second in the laminated clays, silts and sands, and up to 4,500 feet per second in the solifluction material.

The properties of the tillite given in Table II indicate that the compressive strength of the rock correpsonds to a weak sandstone (Krynine and Judd, 1957), but its tensile strength was better than that usually found in sandstones.

The weathered zone extends into the tillite, and it has not been possible to recognize whether an old weathered surface, indicative of exposure between deposition, exists at the top of the tillite.

ACKNOWLEDGEMENTS

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Thanks are due to G. E. A. Hale and G. Rawlings of the Commission, J. L. Davies and M. R. Banks of the University of Tasmania, and E. Derbyshire of Monash University for helpful discussion.

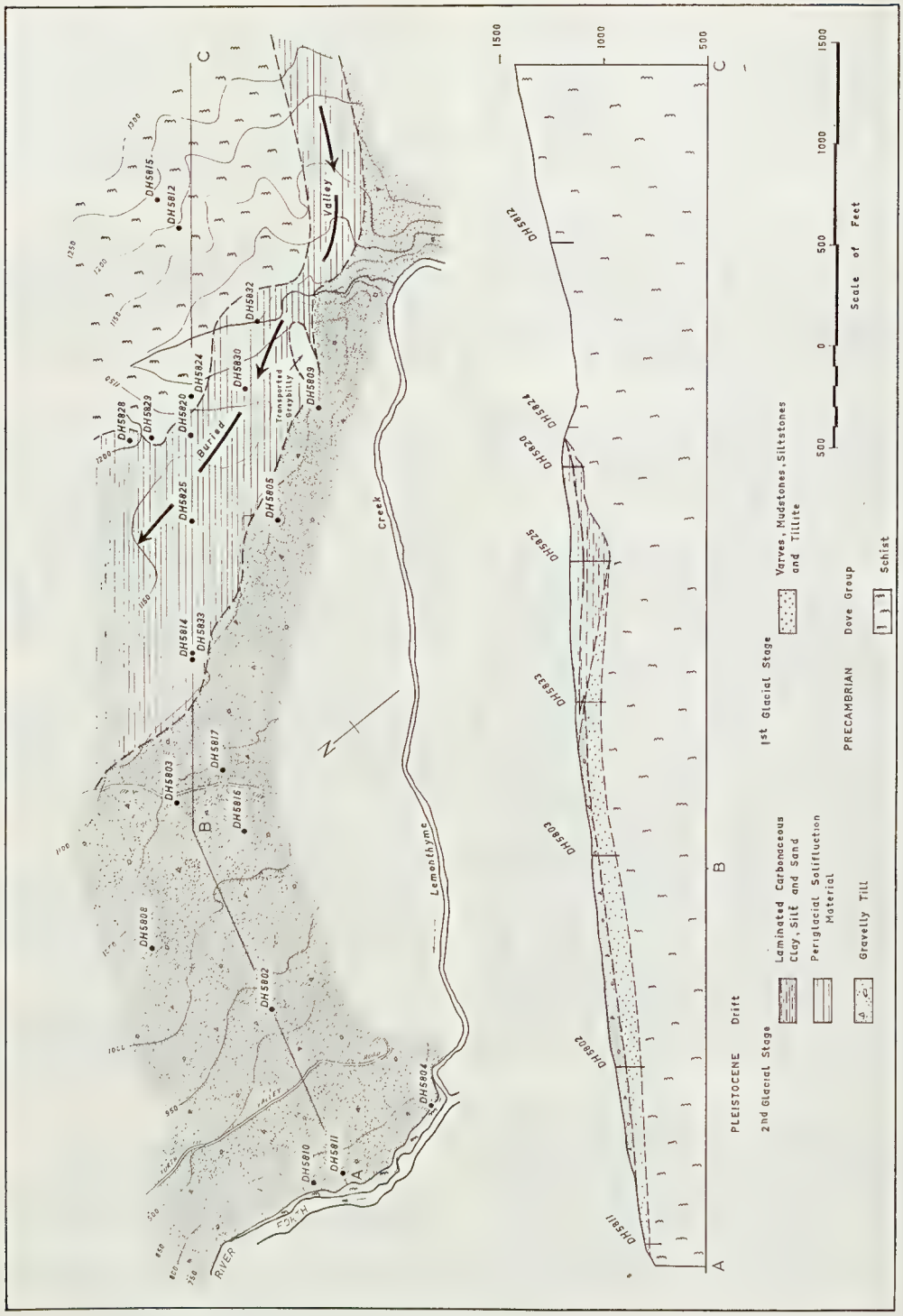

FIG. 5.—Lemonthyme Penstock Line.

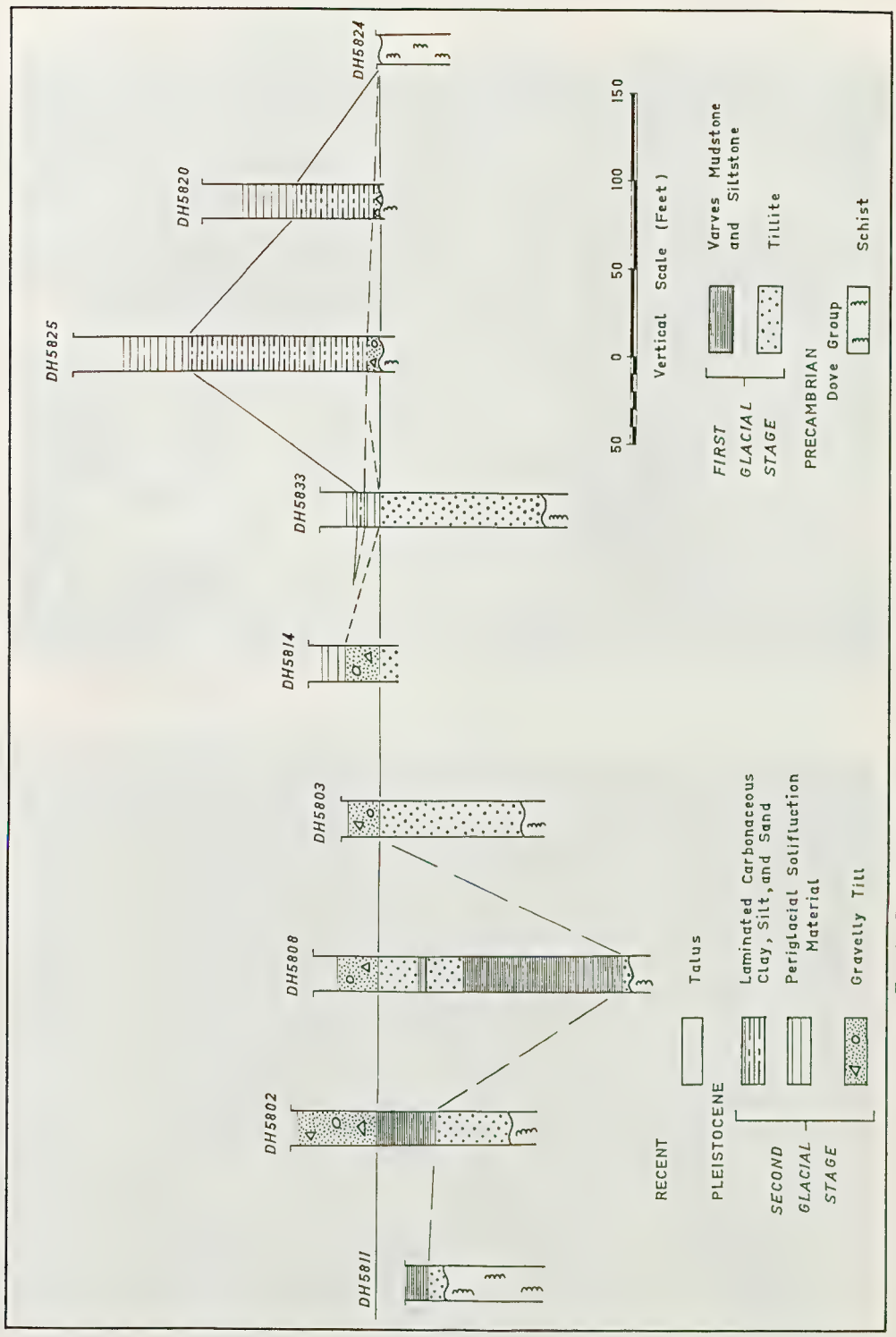

FIG. 6.—Stratigraphic Cross-sections along the Lemonthyme Penstock Line.

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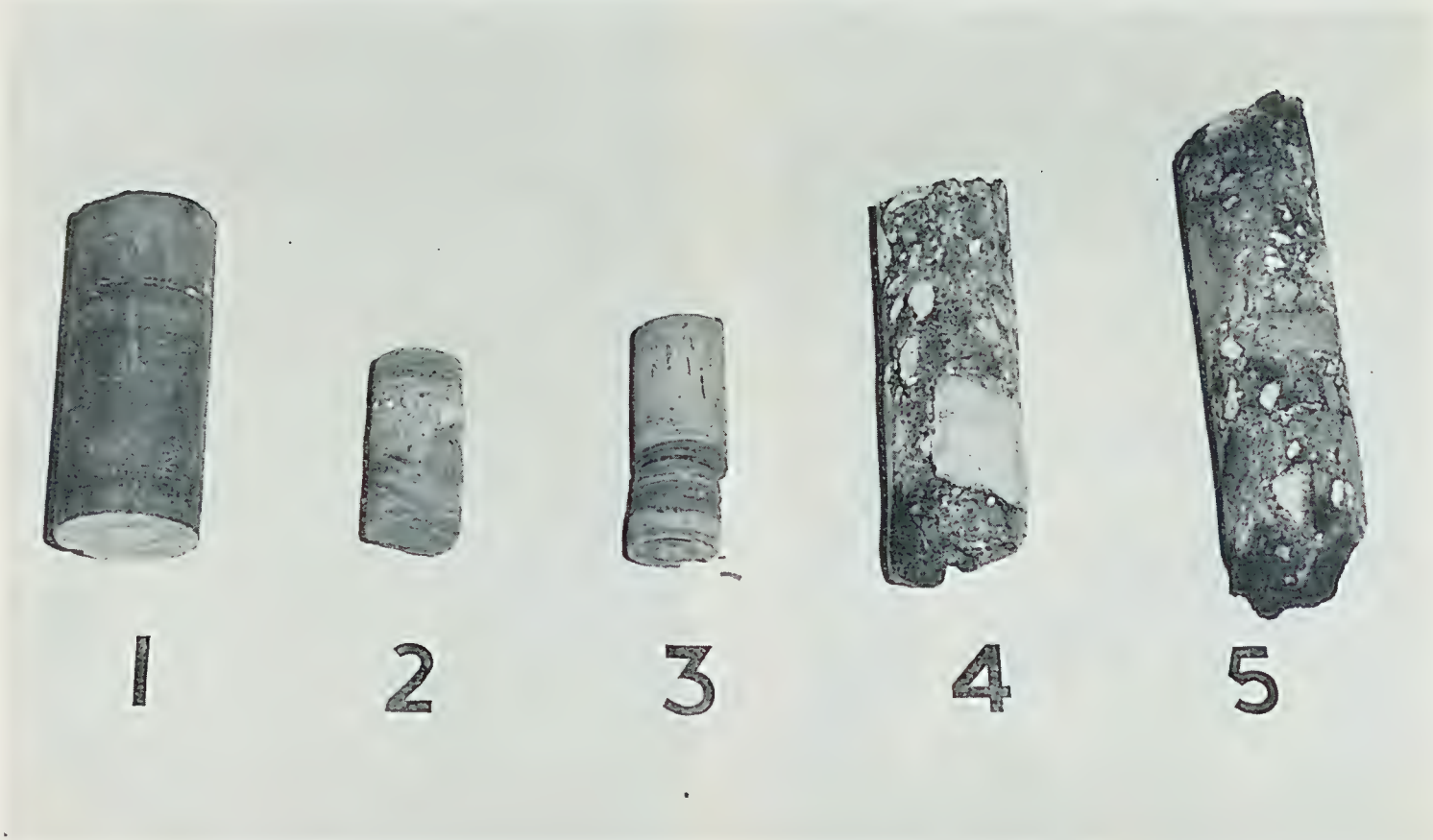
PLATE I.

Fig. 1. Bedded sand and gravel adjacent to the Mersey-Little Fisher Road above Rowallan Damsite.

Fig. 2.—Bouldery till overlain by a basalt erratic in a cut on the Arm Valley Road.



Cores from the Lemonthyme Penstock Line. 1. Interbedded carbonaceous clay, silt and sand. 2. Pebbly layer in interbedded mudstones and siltstones. 3. Interbedded varves, mudstones and siltstones. 4. and 5. Tillite. The numbers are 1 inch high.

NOTICE OF A CHANGE IN THE LOCATION OF PARATYPE SPECIMENS OF ONISCOIDEA (CRUSTACEA, ISOPODA)

(From Miss Alison Green, now of Department of Zoology, University of Otago, Dunedin, N.Z.)

Notice is given that a paratype male and a paratype female specimen of each of the species of Oniscoidea listed below, which were formerly lodged in the Department of Zoology, the University of Tasmania, Hobart, have now been transferred to the Tasmanian Museum, Hobart.

Styloniscus maculosus—Green, 1961.
Styloniscus squarrosus—Green, 1961.
Plymophiloscia thomsoni—Green, 1961.
Plymophiloscia tasmaniensis—Green, 1961.
Plymophiloscia notleyensis—Green, 1961.
Plymophiloscia ulverstonensis—Green, 1961.
Cubaris hickmani—Green, 1961.
Cubaris tasmaniensis—Green, 1961.
Cubaris sulcifrons—Green, 1961.
Cubaris tamerensis—Green, 1961.
Echinodillo cavaticus—Green, 1963.

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POLITICAL SCIENCE AS A SCIENCE

By

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University of Tasmania

[ABSTRACT

The question of the definition of "science" in this context, and the nature and object of the work of the political scientist. Academic roles and responsibility in the field of practical politics are not separable, and the political scientist has no sovereign control of his "material", but is partially subjected to environmental influences. Schools of thought, scepticism and empiricism, and the weaknesses of modern political science. Confusion with the principles of natural science; the example of H. D. Lasswell. Behavioural scientists and modern trends.]

Science according to my dictionary, is "knowledge systematically arranged", and, after dealing with the definition of applied, natural and pure science it adds the *obitur dictum* that political economy is known as "the dismal science". Now the fusion of political and economic studies was the first step taken in the 19th century, in the evolution of the modern academic discipline which has become known as Political Science, and there are those today, like Prof. Hans Morgenthau in his "Dilemmas of Politics" (Univ. of Chicago Press, 1958) who argue that at the present time Political Science is often as dismal a subject as political economy once became. Yet political science is as old at least as Plato's "Academy" or as Aristotle's eternally modern works on politics and ethics, and indeed if ever this subject becomes a dull, or a dismal science, it must be because the methods, the objects, and the imagination of political scientists are irrelevant or incomprehensible to the people they ought to be addressing.

Doubts are often expressed about Political Science, and questions are raised as to whether it is a science at all. Some academicians cloak their uncertainty about it by calling the University departments in which it is studied Departments of Political Studies, or even more broadly Departments of Social Studies, the word "science" is tacitly dropped. Politics, they say, is an art; and it is an aspect of life which is too unpredictable and too intractable to the application of scientific methods of analysis, to qualify as a science. But these propositions of course are based upon a misunderstanding of the word 'science', which, we have seen, in its general meaning is knowledge systematically arranged; but again, as the UNESCO Survey of Contemporary Political Science (Publication No. 426, Paris, 1950) indicated in 1950, this systematic arrangement could apply to "acquired knowledge verified by accurate observation and logical thought", or more broadly to "the sum of co-ordinated knowledge relative to a determined subject", which would make empirical verification less necessary to the systematisation of knowledge (ibid, p. 3). In concluding that the latter definition should apply to the UNESCO panel of scholars who contributed to the Survey seemed to be saying that Political Science is not perfectly scientific in so far as strict empirical verification is not always necessary to it, and that this was certainly borne out when methodology in political science was examined. Experts in the methodology of political science, the authors of the Survey reported, "are wont to speak of a variety of methods: philosophical, dialectical, juridical, historical, sociological, psychological, economic and normative methods, methods of liberty and of the natural sciences, experimental, integral and statistical methods, &c.", and they lamented that "the outstanding feature of this terminology is perhaps its ambiguity". (ibid, p. 3-4). That would seem to be the understatement of the year. At any rate, no political scientist would appear to have mastered all these methods, and not all have agreed that some of them are proper in the field of political science. All political scientists show, however, their individual predeliction for methods selected for their propriety in the study of particular interests and, to be really outstanding, have to show great ability in handling interdisciplinary skills. No wonder, therefore, that the first professor of political science in the University of Cambridge remarked in his inaugural lecure in 1928 "that many of his hearers regarded the subject of his chair as 'certainly nebulous, probably dubious and possibly disputatious'". (W. A. Robson, The University Teaching of Social Sciences: Political Science, UNESCO, 1954, p. 16).

Not only to the uninitiate, then, would it seem that political scientists cannot even agree upon the scope or set limits to their alleged discipline, or indeed to the object of its study. Indeed, for Maurice Cowling of Jesus College at Cambridge, political science as an academic discipline is non-existent. "Political Science", he writes (The Nature and Limits of Political Science, Cambridge, 1963, pp. 209-210—cf. p. 1ff) "the taking thought to

deal with each situation by hypothesis and experiment", he calls it, "is . . . in an academic setting, an impossibility. In an academic setting," he went on, "hypotheses are tools for the further elucidation of a subject matter and they have no relevance to anything else. Political explanation exists here as philosophy and history, and nothing else. Political science, sociology, social administration, international relations, criminology, comparative institutions and comparative government, when looked at critically, dissolve into these two disciplines: and if they do not, they have not been looked at critically enough." And, he goes on, "The only political science, in this sense, goes on in the world of practice and the only political scientists are ministers and members of parliament, ambassadors and heads of department, kings, princes, citizens and revolutionaries who are, like historians, physicists and philosophers, responsible for the subject matter on which they work. Professors of Political Science", he added, "who want to engage in political practice (by standing for Parliament, writing in newspapers, advising governments or joining the City Council) are free to do so. But they are, so far as they do this, abandoning their academic function for a practical political one. To do so may, if they are lucky, help them to illuminate the academic subject matter. But the only rational action to which scholars, as scholars, are committed, the only moral action to which they are commanded and the only 'social responsibility' to which their professional position compels them, is to use their energies in order to explain in its full diversity as much as they can of the nature of the world in which they live."

This is, perhaps, a view which would be agreeable to many. But Dr. Cowling is to my mind not entirely convincing. The distinction between the scholar and the practitioner is not an absolute one, as he at least suggests, but moreover explanation, as he, in fact, says (p. 210) "is a form of action". It is never explanation for its own sake, but for some purpose; and to say that one explains for academic reasons is nonsense, or at any rate it confuses the method with the object. Explanation, I would argue, comes about when a question becomes significant, and the kind of question asked by political scientists is always subjective to the age and place in which it is put. But secondly it it always asked for a purpose. Thus one may ask "How does the constitution of, let us say, Britain, or the U.N. work?" not simply with a view to explaining its parts, but in order to exercise judgement; for some end. Does it work properly, efficiently, is it satisfactory in carrying out the purpose for which it came into being? And willy nilly, implicitly or explicitly, the scholar will ask what may be done to it to make it serve its purpose better? Or whether indeed its purpose ought to be changed? Thus even academic explanation is a social and a political act. It only has force and significance, of course, if it is seen to be relevant to actual problems of life, and in the field of political science that means in practical political life. The difference between the academic political scientist and political practitioner is, then, that the first when properly so called, in contradistinction to the second, applies his mind without undue restraint of loyalty to party rules or particular political ideologies, to explain particular or general problems in order to discover the truth and to serve mankind. He undertakes research, and he teaches. And teaching is never simply the passing on of information or of explanation but a process of training people to use judgement, and the use of judgement means the seeking out of criteria of right and wrong, of excellence and of inferiority. It is, in short, also a process of character formation as well as of intellectual training. Political scientists are involved, in fact, not only in explanation but also in making. They may inform official opinion, guide public opinion, and direct through widening circles through schools and professional associations and societies the attention of administrators and politicians to principles and practices which deserve rejection, modification, or acceptance, because one of these things will make the governmental and the social system more just, more efficient or more economical. Moreover, nowadays not infrequently, academic political scientists, like academic economists, are formally called in to provide professional or technical advice to government departments or international specialised agencies, or they are employed to undertake special surveys and compile official reports. In all this activity they are involved in an increasing responsibility in policy formulation and creating a consensus of opinion on vital matters in national and international affairs. Thus Charles Merriam said with some truth some forty years ago that (New Aspects of Politics, University of Chicago, 1925), political scientists are more than concerned with the methodology and scope of social research, they are concerned with social formation or as some would put it, 'social engineering'; and he added that "We might make the coming generation aristocrats, democrats, communists, nationalists, or internationalists at will, assuming that we were prepared to devote the necessary time and patience to the construction of the machinery for the purpose of social and political education". (p. 203). Nor does he mean only secondary and tertiary education, but the constant re-education of the citizens (p. 206). "The public opinion", he says, "that rests chiefly upon tradition and custom, or upon transparent rationalisations of interest, or upon ignorance of fundamental relations between economic and social interests and political action can no longer be reckoned as an adequate basis for a government". (p. 209). He had in mind then an applied science of politics and of government, just as, indeed, had Aristotle.

In his views, though, Prof. Merriam overemphasises perhaps the role of the political scientists for, as Aristotle was the first to point out, the manners and minds of men are formed by three factors, nature, habit and rationality (Politics, Bk. VII, para. 1332b), and it is not easy, as all political and social studies testify, to bring these three determinants of action into harmony with each other. This indeed is the central problem of the political scientist.

Nor indeed, as a further comment upon Prof. Merriam's argument, is the political scientist a sovereign educator, for "It is", Maurice Cowling wrote, "the whole of the education and the whole of a religion that a man has, not just his reflective philosophy, which determines what part he sees

of the world and what he will think it necessary to do in it", (p. 208), and in this sense neither the academic political scientist nor the practitioner of scientific politics has full control of his material. But the difficulties of the political scientist do not stop there. For it should be transparently clear that the political scientist is himself a creature of nature, habit and rationality, and though his natural self may be under a wide measure of command because of disciplined and civilised habits and because of the intense individualism which springs from the cultivation of a questioning and rational approach to the problems of life, yet his mind and nature will still be profoundly affected by the social and intellectual community in which he lives. And in that context too, what work he does will reflect at least a compromise between his free will and the expectations or demands of his society. Thus it is that there are national schools of political science: Prof. Hans Morgenthau argues that American departments of political science "were established . . . not for the purpose of theoretical understanding, let alone philosophical speculation, but primarily for meeting the practical exigencies of the day", that is to provide administrators, and to train practical politicians. This, he said, was the limit of expectation placed upon American colleges and universities in an age which cherished only the utilitarian (Dilemmas, pp. 9ff.). On the other hand, German political science, it is sometimes claimed, is expressive of the traditions of German legal science, and French of the Roman legal tradition; and in the Soviet Union, under the impact of Marxism, "political science" (reports the UNESCO Survey) "is merely a secondary aspect of sociology which is centred in political economy". (pp. 7-8).

Political scientists, then, are subject to environmental factors which not only affect directly their intellectual freedom, as in totalitarian states, but which more subtly condition their thinking according to their degree of involvement in religious, political, or other movements and in their cultural environment, and also according to what might be called the interdisciplinary pressures which are current from time to time. Among these influences from other branches of learning at present would clearly be listed (1) demographic and ecological studies in a period of tremendous human population growth; (2) sociological studies of populations in areas of rapid economic change when agricultural science and industrialisation are introduced or where a continuing technological revolution is changing industrial, economic and administrative patterns, and consequently political behaviour; (3) military science, because the consequences for national politics and international relations of modern military weapons are so great; (4) economics, because, for example, the consequences in domestic politics of the attainment of the Welfare State and in international politics of the growing gap between States with affluent societies and those with struggling economics, urgently call for remedial steps by national governments and international agencies; and (5) anthropology, (taken in the widest sense of the Oxford English Dictionary as the 'Whole science of man'; and the 'physiological and psychological science of man',) because, *inter alia*, the strict egalitarian principles of 18th century European rationalist political theory have so generally been made the basis for political action when in fact differences between, on the one hand primitive societies and on the other 'advanced' societies and also amongst advanced societies as such, makes political egalitarianism impractical whether it is applied to individuals or to states. Besides it is evidently impossible to introduce it in some multi-racial states without actually introducing injustices which may be more sharply felt than the old ones. Consequently, the political and administrative machinery of government and also legal systems have to be carefully appraised and modified to avoid renewed or new tensions in modern states and between them. Sixthly, then, political science is also influenced by administration and legal science. Even in advanced societies, then, cultural heritages and what may be called inherent differentiating factors such as racial, religious, and geopolitical, as well as ideological considerations, control the processes of question and answer, of the interpretation of legal and moral rules, and of social and political analyses made by policital scientists.

Any such listing of influences to which political scientists are subjected, such as I have just attempted, emphasises the fact that their subjectivity is broadly of two kinds: (1) they are themselves members of diverse societies, and their studies tend to reflect their inheritances as well as sometimes differing environmental problems; but (2) they live at present in a revolutionary age when much of their inheritance seems irrelevant to an understanding of their own times, or to salvation from fearful dangers foreseen in the future. Where political scientists perceive these antagonistic influences the order of questions which they ask undergoes profound changes, and at the same time a profound scepticism moves many of them to perhaps an extreme reliance upon empirical testing so that political science withdraws itself from theoretical exploration and speculative thinking and becomes for some at any rate a new dismal science concerned with the collection of data and its systematic arrangement, such as is indulged in by some scholars specialising for example, in the statistical analyses of elections. Or conversely the same disillusionment with reflective theory and established moral resources leads to the mathematical or formulative projection of ameliorative and allegedly practical programs of elective, political and administrative organisation without sufficiently taking into account that man's social behaviour and exercise of political choice rarely conforms to the objects of such programs. Thus some political scientists, to quote Morgenthau (op.cit. pg. 19), "retreat ever more from contact with the empirical world into a realm of self-sufficient abstractions". This fault has been "aptly called", he says, the "new scholasticism" and what it does is to dissolve "the substance of knowledge into the processes of knowing; . . . to think about how to think, and to conceptualise about concepts". It means "regressing ever further from empirical reality until" the patient (as one feels obliged to call this type of scholar) "finds the logical consummation of his endeavours in mathematical symbols and other formal relations . . . The apparent precision of his

categories" Morgenthau then says, "tends to go hand in hand with an often shocking imprecision of his vestigal substantive thought; for, to the extent that objective reality demands qualitative evaluation, formalism either misses the point altogether or else distorts it".

It is not surprising indeed, that many scholars, shocked out of the security given by traditions and beliefs which have been undermined, and disillusioned about their ability to rest their learning upon sure religious or philosophical foundations, should either over-emphasise the empirical, or withdraw from both traditional speculation and empirical verification and escape into the exercise of what they might call pure *avant garde* rationalism. But the most rewarding part of modern political science is the development of empirical testing to prove the soundness of classical theories and application of the results to the reformulation of ideas in all fields of knowledge about mankind in order to smooth the path of adaptation to new orders of existence. Ideas and practice are therefore brought continually into a renewed and approximately harmonious relationship.

I am reminded in this of the frustration which Bishop John Robinson reports is felt by many Christians whose life of prayer and devotion is purely formal because their religious life is identified with a physical place (the church) and with a spiritual place (which is not of this world); and of his injunction that religion is a way of living here and now and prayer and devotion is performed serving ones fellows in accordance with ones faith in God. ('Honest to God' by J. A. T. Robinson. S.C.M. Press, 1963). Theology and exegesis are indeed sharing the shocks of our time which is revolutionising our knowledge of things and altering our methods of ascertaining the truth for our times in all fields of learning. And the fundamentally interesting thing is not the scholastic aberrations which ensure, but the reformulation of the old and perhaps its evolutionary development, with at times some discarding of what is now not credible or needed and with some addition of knowledge and emphasis of what is now needed, in a way which revitalises faith and points to exciting prospects for research, planning and development. In effect, in the social sciences as in theology and the experimental sciences, formalism whether in theory or practice is taking hard knocks, and theory and practice are being wedded together in action. Just as, then, religion is showing a tendency to come out of the pulpits into the streets so even more generally the political scientist is coming out of his ivory tower to try his rationalism in the hard school of practical affairs. And it would surely be wrong to accuse them of sacrificing political objectivity in doing so, for apart from the fact that experience may improve their objectivity it would be paradoxical to demand a self-denying ordinance from those who have devoted the most serious study to political life and institutions. It suffices only to say that of course the political scientist should recognise his special responsibility in this matter, since, in the words of Professor R. H. Brookes of Wellington, "Precisely because he studies the subject seriously, people may give some weight to his remarks". Thus "to justify their attention, he must not merely achieve an understanding of the system he's criticising; he must also cultivate adequate standards of criticism", must draw, indeed, upon the masterpieces of political theory and make articulate anew "the assumptions on which alternative political systems may be based, thereby challenging one to clarify, and perhaps to modify, the basic assumptions underlying . . . (other) . . . political preferences". (R. H. Brooks, The Art of the Possible, Inaugural Address, The Victoria University of Wellington, 1962, pg. 12.).

Now, what we have established thus far in this lecture, is (1) that the political scientist is subjective to his environment, and that (2) he ought not to do his work esconced in an ivory tower, and that in fact he seems increasingly to work as one who does have in view the application of his adumbrations to real situations. He is then, no different from the physicists, chemists and others who also have to work from existant theories of energy and matter, and who are concerned with the advance of scientific knowledge for practical ends. Some have concluded in consequence that political scientists should go about their work in the same way. But the attempts of those who think of political science in the same terms as natural science have lead to some unhappy results.

This one may illustrate perhaps by quoting from the work of one of the most renowned of modern social scientists, Harold D. Lasswell, and considering what in fact happened to him. "One aspect of the task of the systematic student of politics", he wrote, "is to *describe* political behaviour in those social situations which recur with sufficient frequency to make *prediction* useful as a preliminary to *control*". (Quoted in 'Essays on the Scientific Study of Politics', Ed. H. J. Storing, New York, 1962. pg. 227, by R. Horwitz). In applying a lifetime of study to this intention Lasswell turned his back formally upon political philosophy as, to quote his words, "metaphysical speculation in terms of abstractions hopelessly removed from empirical observation and control". (quoted from Lasswell, 'Power and Society', p. x, Storing, op. cit. p. 303). For him, in fact political philosophy was equivalent to ideology, the classical theorists having generally, he argued, established doctrines in justification of their own political preferences. To replace such unscientific formulations Lasswell strove to contribute towards the formulation of an all-encompassing scientific political theory according to which all social structures and the resultant political philosophies could be understood (ibid. p. 228f.). Yet Lasswell himself was dedicated to a political ideal: he was a man "deeply intent on making Democracy a working institution" (Lasswell: The Analysis of Political Behaviour, p. vii, London, 1951), and this confusion left his thought, in the words of Ralph Horwitz, "impaled on the horns of an irresolvable dilemma". His science became manipulative rather than descriptive, it was put to the service of propaganda rather than simply to a cool analysis of social behaviour, and his careless regard for political philosophy as a discipline which had formed even his preference seems to

have left him unaware that he had become, master propagandist though he was, the victim of a subtler propaganda than he could invent. (Storing, p. 303f.)

From the point of view of converting political studies into a quasi-exact science, then, or of establishing model constructs as criteria by which to judge real social situations and their political consequences Lasswell was a failure. But in other ways he, and a whole generation of behavioural scholars have in fact made it possible for political analysis to reach new depths and to turn it to good purpose in the practical assessment of social situations by political parties and departments of state. They did this by adding a new perspective to census-taking, by perfecting methods of opinion analysis, and behaviour analysis in authority structures of both informal and formal kinds, as in social clubs, in trade unions, in military forces, and in state bureaucracies. The results have sometimes been startling, as for instance to prove wrong by empirical verification Marxist prophecies of the encreasing proletarianisation of capitalist society. For society in advanced industrialised countries develops highly elaborate authority structures which distribute wealth and political power in ways unforeseen by Marx, and which leads in fact to a diminishment of the social category which Marx identified with the use of the word mass, to such a point indeed that the real mass lies above it. (Cf. R. Dahrendorf, Class and Class Conflict in Industrial Society, London 1959). Another vital example would do here. It has been a trait of many political theorists, prominently amongst them in our own time, the Marxists, to suppose that by a perfectly just redistribution of wealth and power classes would disappear and therefore the tensions between them would disappear also, so that in due time the whole world would dwell in peace as all its peoples were habituated to communist norms of social justice. But modern behavioural research unhappily proves Aristotle right. It is not simply economic factors which cause social differences, and tensions between classes, and violence in society. Authority relationships which even communist society could not eliminate cause it too; and so do a whole pandoras box of human prejudices arising from group relationships (e.g. as between peoples of different physiological type and skin colour). And though it is true that a good deal of research has traced the causes of particular prejudices and made it possible to eliminate them by legislation and education, yet the situations out of which prejudice involuntarily arises, and which can be exploited by political manipulators, are not always predictable and occur in such variety that a general control is impossible of achievement.

The behaviòralists have therefore served us well in certain directions.

Not least is challenging many accepted views with regard to the traditionally most important part of political studies, namely institutions and administrative structures. It was often the case especially perhaps in countries governed in the British tradition, to suppose that administrative structures were a-political or at any rate were a negative factor in the implimentation of political policies. One does not have far to seek in history to prove this assumption wrong, but still too many scholars are content with descriptive analysis based upon constitutional documents or similar evidence, and give too much credence to the assumption that bureaucrats, including civil servants, are not part of an over-all authority structure (what the sociologists call an imperatively coordinated association), extending from the highest political or decision-making offices down to the daily routines of the humblest members of society. Behavioural studies have proved that authority roles where-ever exercised in a social group such as one may take a nation-state to be, have social and political content as well as administrative meaning. That is to say, that while the formal legal organisation of institutions does institutionalize the character of human behaviour and impose differential functional relationships upon people who categorise each other according to place and role in the formal authority hierarchy, at the same time, informal human behaviour and individual or class expectations or desires deriving sometimes from sources outside the functional roles involved, create tensions within institutions, and bring about organic changes in them, which make even the most carefully written constitutions inadequate tools of political analysis. A classic example would be the constitutions of the U.S.S.R. and of the C.P.S.U., but it affects all institutions. (Vide S. K. Bailey, 'New Research Frontiers of Interest to Legislators and Administrators' in Research Frontiers, Research Frontiers in Politics and Government, Brookings Institution, 1955, pg. 13 ff.) As a consequence the conventional use of words like 'executive', 'legislature', 'political party' and bureaucracy' in the sense of formal categories which enable scholars to indulge in the comparative analysis of governments by comparing their formal constitutions is now recognised to be unscientific. An example would be the highly complex considerations which apply to the comparison of ministerial cabinets in British Commonwealth states, for even the most tentative probing must lead one to assume that they are all different kinds of organisms differently articulated to state departments, and legislatures, and to party caucases; and equally important perhaps, are differently regarded by the people at large whom they govern. Thus new criteria of comparison, if comparison there must be, must be found. (*Vide*: D. B. Truman, The Impact on Political Science of the Revolution in the Behavioural Sciences, in Research Frontiers, op. cit. Chapter 8.) Nor is this exercise irrelevant, for in a world in which inter-governmental co-operation and even supra-national institutions are of increasing importance, the provision of properly trained personnel and the development of a more general understanding of the processes of decision-making and execution are of very great importance. Not only in national governments, but in international organisations, for it becomes clearer that a nominally a-political secretariat or international civil service, as in the U.N., does become what its creators so often naively suppose it won't become, namely, a *positive* force in the implimentation of policies implicitly as well as explicitly written into

the charter or treaty by which the organisation is set up. (*Vide*, UNESCO Report on National Administration and International Organisation, A Comparative Survey of Fourteen Countries, Brussels, 1951.)

I cannot canvass here, with any hope of success the new approaches which are being made, and the new principles which are being established, in the study of politics and government. Suffice it so say that in many ways political scientists are making new maps as significantly different from the old as the geographical charts of the world which followed the discovery that the earth was a globe and not flat. And their new maps are becoming as complex and as differentiated as the geographer's and geologists' maps. And so they must, for they deal with the whole man, in his whole environment and with all kinds of men in their kinds of environment. Thus there are many specialists going under the general name of political scientists, and it is not given to a general practitioner, or indeed even to a specialist of one branch of the science, to be able to move with equal facility through all fields of learning and research in this great subject.

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GEOMORPHOLOGY OF THE BUCKLAND BASIN, TASMANIA

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(With 11 text figures.)

ABSTRACT

The Buckland Basin is an exhumed tectonic basin considerably modified by erosion. Its drainage pattern has been altered by river capture. A longitudinal profile of the Prosser shows that the basin is not graded to present day sea level. The theory of the effects of changes in base level is considered. Erosional terraces are described which may be due to Pleistocene glacio-eustatic oscillations in sea level.

The morphology of the floodplain is examined in detail. Types of river channels and the nature of the floodplain alluvium are discussed. Surface morphology of the aggradational Turvey Terrace indicates that the terrace was formed under climatic conditions very different from the present. Depressions on the terrace may be thaw sinks. Measurements of a fossil stream on it, the prior Tea Tree, indicate much larger bankfull discharges. Alluvial fans which may be related to the Turvey Terrace occur along the Eastern Boundary Scarp of the basin.

An attempt is made to interpret and date the alluvial deposits. Aggradation in the basin is probably due to climatic factors causing a change in the load-discharge ratio of the streams. Differences between floodplain and Turvey alluvium are shown. Floodplain alluviation is believed to be due to a mid-Recent period of increased aridity, while the Turvey alluviation is periglacial in origin.

INTRODUCTION

The Buckland Basin is located near the East Coast of Tasmania some forty miles north-east of Hobart. Measuring approximately five miles from west to east and almost the same distance from north to south, it is approximately triangular in plan. On the eastern side it is bounded by a steep scarp, interrupted only where the Prosser River leaves the basin. Steep undercut slopes form a distinct boundary to the north-west. To the south-west the edge of the basin is defined by a row of steep dolerite hills reaching their highest point at Mt. Gatehouse.

As a background to a consideration of the nature and origin of the basin itself, it is necessary to extend the discussion to the whole of the Buckland one inch to one mile topographic sheet. To the south and west the watershed of the drainage basin of the Prosser and its tributaries falls within the sheet whereas to the north the watershed falls outside it. No contoured maps are available for the area to the north.

THE CONTEXT

Climate, vegetation and soils.

The average yearly rainfall in the Buckland Basin and along the coast ranges from 20 to 30 inches (Nicolls and Aves, 1961). In the more elevated regions the rainfall is higher, probably between 30 and 40 inches. It is fairly evenly distributed throughout the year although there is a slight tendency towards a winter rainfall maximum.

The mean annual temperature is probably in the vicinity of 52° F. River valleys and basins experience severe frosts in winter. In Köppen's system the climate is classified as Cfb.

The vegetation is similar to that of the Sorell-Carlton-Copping area immediately to the south where it has been described by Loveday (1957). He found that the vegetation could be divided into three major groupings depending on rainfall. Savannah woodland is characteristic where rainfall is less than 25 inches. With rainfalls from 25 to 30 inches a dry sclerophyll forest develops, while areas with rainfalls exceeding 30 inches may be classified as wet sclerophyll. There is a continuous gradation between these vegetation classes.

The savannah woodlands are mostly cleared unless they are too steep or stony for cultivation. Dry sclerophyll forests are mostly in the natural state except where undergrowth has been cleared to allow rough grazing by sheep. Wet sclerophyll forests are found in the higher rainfall areas, in the Prosser's Sugar Loaf-Middle Peak area to the south-east and around Blue Tier to the north of Buckland as well as in moist sheltered valleys within the drier regions.

The soils of the Buckland Sheet have been described by Loveday and Dimmock (1957), who produced a reconnaissance soil map on a scale of 1 inch to the mile. The main soil divisions are based on differences in lithology. Podzolic soils on sandstone, feldspathic sandstone, mudstone and dolerite are described, and in addition there are small areas of brown and black soils on dolerite as well as krasnozems, black and red-brown soils on basalt. The only soils of large areal extent are the podzolic soils on dolerite (251 sq. miles) and sandstone (79 sq. miles). Soils of alluvial deposits (30 sq. miles) are mapped as a single unit. These soils vary considerably both in age and in mineral composition depending on the lithology of the terrain from which they have been derived. Since alluvial deposits are not differentiated, the soil map is of limited use to the fluvial geomorphologist. In the Buckland Basin there is a sharp contrast between

alluvial soils derived from sandstone and dolerite. In the latter there are also important differences between the soils of the present floodplain, the Turvey Terrace and the fans. These differences will be discussed later.

Lithology

The oldest rocks outcropping in the area (Department of Mines, 1958) are flat-lying to gently dipping Permian marine mudstones of the Malbina Formation (formerly known as the "Woodbridge glacials"). They are exposed along the course of the Prosser River downstream from the Buckland Basin and also to the south of the Tea Tree Rivulet just before its confluence with the Prosser. The mudstones are overlain by a thick sheet of Jurassic dolerite. Due to their limited outcrop of approximately one square mile the Permian rocks are of little importance in the geomorphology of the Buckland Basin. Their susceptibility to fluvial erosion is similar to that of the Triassic sandstones.

Triassic rocks outcrop extensively in the region, occupying a roughly wedge-shaped area with the point of the wedge formed by the Buckland Basin. They have been mapped as two units: (1) The older Ross Sandstones and Knocklofty Sandstones and Shales. (2) The younger Feldspathic Sandstones and New Town Coal Measures. The use of these formation names is very questionable. In discussing the Triassic System in Tasmania, Hale (1962) has already pointed out the difficulties of correlating strata even over short distances. This is due to rapid horizontal variations in thickness and lithology, repetition of similar beds and the lack of marker beds and fossils. The Buckland region is a considerable distance from the Triassic type sections and the lithology of at least part of the succession is rather different. (1) The older "Ross Sandstones and Knocklofty Sandstones and Shales" consist in part of a succession of several hundred feet of cross-bedded sandstones rich in halite and epsomite. These salts are very susceptible to chemical weathering and, where slopes are steep, shallow caves are formed by atmospheric weathering in layers rich in these salts. The unit as mapped also includes sandstones with thin bands of shale. The latter contain poorly preserved plant fossils and outcrop in one place along the bank of the Prosser in the Buckland Basin (grid ref: 560540). (2) The younger "Feldspathic sandstones and New Town Coal Measures" outcrop in two small areas only: one along the Back River near "Stonehurst" and the other at Tiger Hill between the Bluff and Sand Rivers. The rocks consist of sandstones and shales containing bands of coal up to three feet thick. Both areas have been mined for coal on a small scale 50 to 100 years ago.

From the geomorphological point of view only the rocks discussed under (1) are of real importance. They underlie the Buckland and Runnymede Basins and occupy large areas to the north and north-east especially in the drainage basins of the Bluff and Sand Rivers. The Triassic sandstones are more liable to weathering and erosion than the Jurassic dolerite thus partly explaining their coincidence with basins. However, to the north and north-east of the Buckland Basin they outcrop in country of strong relief where the upper courses of the Bluff and Sand Rivers have cut deep gorges.

The Jurassic period is represented by thick sills of dolerite, which are intruded at various levels into the Permian and Triassic strata. Individual sills may be 1000 feet or more thick. They are often transgressive, hence cannot be used as stratigraphic markers. As well as sills there are dykes and necks of dolerite. This rock occupies by far the greatest area on the Buckland Sheet. The Buckland Basin is bounded by extensive areas of dolerite to the west, east and south. The most resistant rock, it outcrops in nearly all the higher country. This is so despite the fact that it is susceptible to both chemical and physical weathering. It is composed mainly of two minerals: augite and labradorite both of which are susceptible to chemical weathering. Physical weathering is promoted by the well jointed nature of the rock making it particularly vulnerable to frost wedging under periglacial conditions.

Tertiary freshwater sediments are also represented in the Buckland Basin although they are not shown on the geological sheet. The presence of Tertiary sediments was first suspected by Loveday and Dimmock (1958) who produced a reconnaissance soil map of the Buckland Sheet. They described an area of lateritic soils (1 sq. mile) in the Buckland Basin stating that these were "considered to have been developed on lake sediments similar to those of the Launceston Tertiary Basin, with which the soils have much in common". An outcrop of these sediments was discovered by the writer who found light grey clays, underlying Quaternary terrace and floodplain deposits, in the bed of the Tea Tree Rivulet up to three feet above low water level (plate 3). This outcrop is intermittent for a distance of several hundred yards but the most extensive outcrop occurs at grid ref. 597516 just north of the boundary fence between Court Farm and Mr. Turvey's property. The clays contain abundant vitrinized fossil wood and lenses of paper coal up to 6 inches thick, interbedded with thin sandstone beds. Polished sections show that the clay is laminated. The laminations are wavy and one layer of clay between two sandstone bands showed strongly convoluted laminations. Deformation of the clay laminations is probably due to post-depositional compaction. The sediments are flat lying and are not jointed. In one outcrop root voids penetrate the top six inches indicating the presence of vegetation before the deposition of Quaternary alluvium. An auger hole (t) was put down in the bed of the Tea Tree Rivulet and went through 4' 4" of clay with three bands of sandy material before striking a log of vitrinized fossil wood.

The age of the clays is critical to the interpretation of the evolution of the Buckland Basin. Townrow (in press) has found a rich flora, including abundant conifer remains, and has already described the following new species from the locality: *Podocarpus strzleckianus, P. tasmanicus, P. setiger, P. goedei, P. acicularis,* and *Microstrobos sommervillae.* Other plant fossils identified are *Coronelia*

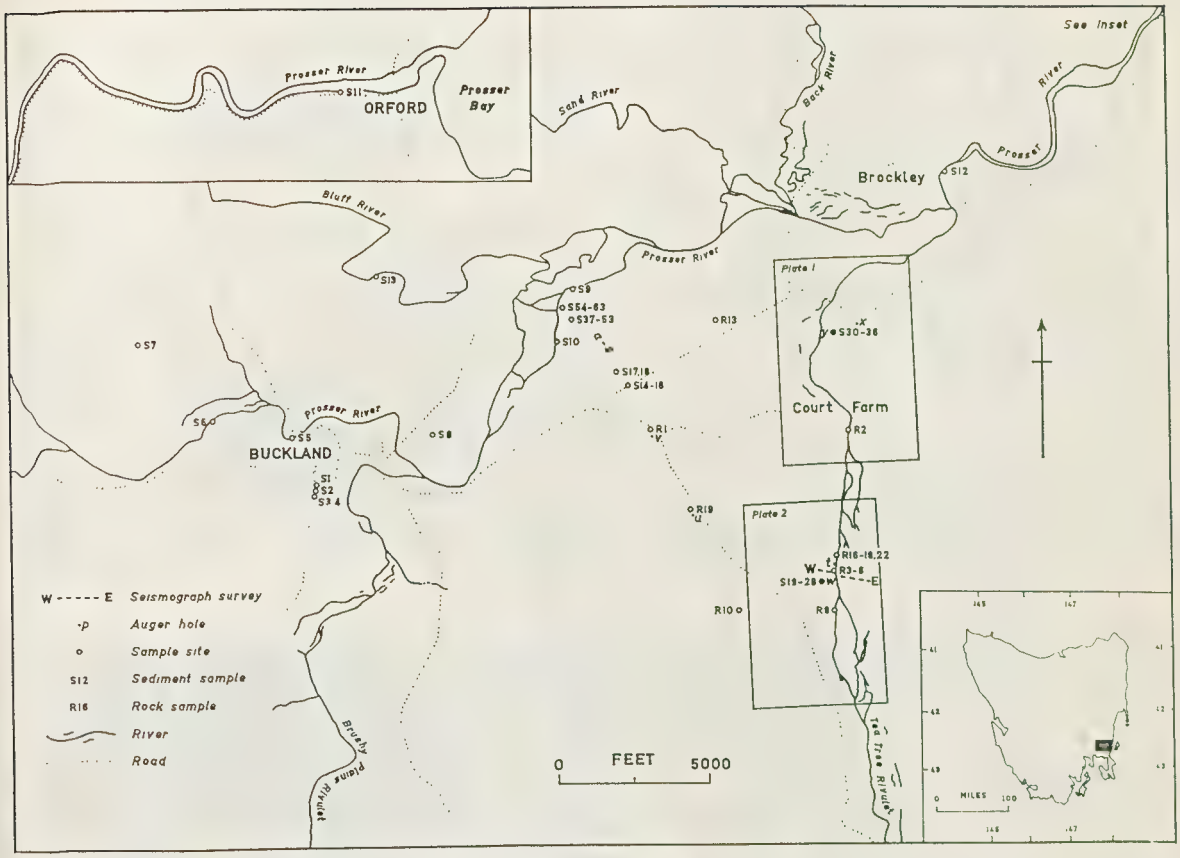

FIG. 1.—Index and sample map of the Buckland Basin.

molinae and a species of *Athrotaxis*. *Coronelia molinae* had previously been recorded only from the Eocene of Chile (Coronel, Buen Retiro) where it was described by Florin (1940) as a new genus and species. Some material was sent for pollen analysis to Dr. Duigan (University of Melbourne), who found that most of the pollen belonged to *Nothofagus*. Several species were present including *N. emarcida*, *N. cincta*, and either *N. goniata* or a closely allied form. *N. cincta* is recorded from Eocene to Lower Miocene and *N. goniata* from the Lower Tertiary. Other angiosperm pollen grains included those of Proteaceae and Casuarinaceae but myrtaceous pollen grains were not observed. There was also an appreciable amount of gymnosperm pollen probably belonging mainly to the Podocarpaceae but including *Trisaccites micropteris* and *Ephedra notensis*. Both of these have been recorded only from Lower Tertiary and earlier deposits. In Tasmania they have also been identified in the Launceston Tertiary Basin in sediments of Palaeocene—Lower Eocene age (Gill and Banks, 1962). The combined evidence of plant macrofossils and pollen analysis strongly suggests an early Tertiary age.

The extent of the Tertiary sediments is difficult to determine because of the lack of outcrop. A seismic traverse across the Tea Tree Valley (fig. 10) showed that, from the outcrop in the bed of the Tea Tree, Tertiary freshwater sediments underlie Quaternary fluvial deposits for at least 1300 feet to the east and 500 feet to the west. The soil evidence together with that from auger holes indicates that the area of lateritic soils described by Loveday and Dimmock is also underlain by Tertiary sediments. This area has been called the "Ironstone Surface" by the writer and will be more fully described later. Similar lateritic soils have also been found on a low swell separating the Turvey Terrace from the present floodplain a short distance south-east of Gatehouse's Marsh Bridge. The maximum extent of the Tertiary sediments is a triangular area of at least 2 square miles in the Tea Tree Valley. It is bounded on the east by the Eastern Boundary Fault which forms a prominent dolerite scarp. To the south-west it is bounded by a line of sandstone hills but to the north the boundary is less definite. It does not extend more than a few hundred yards north of the Tasman Highway and runs approximately parallel to it.

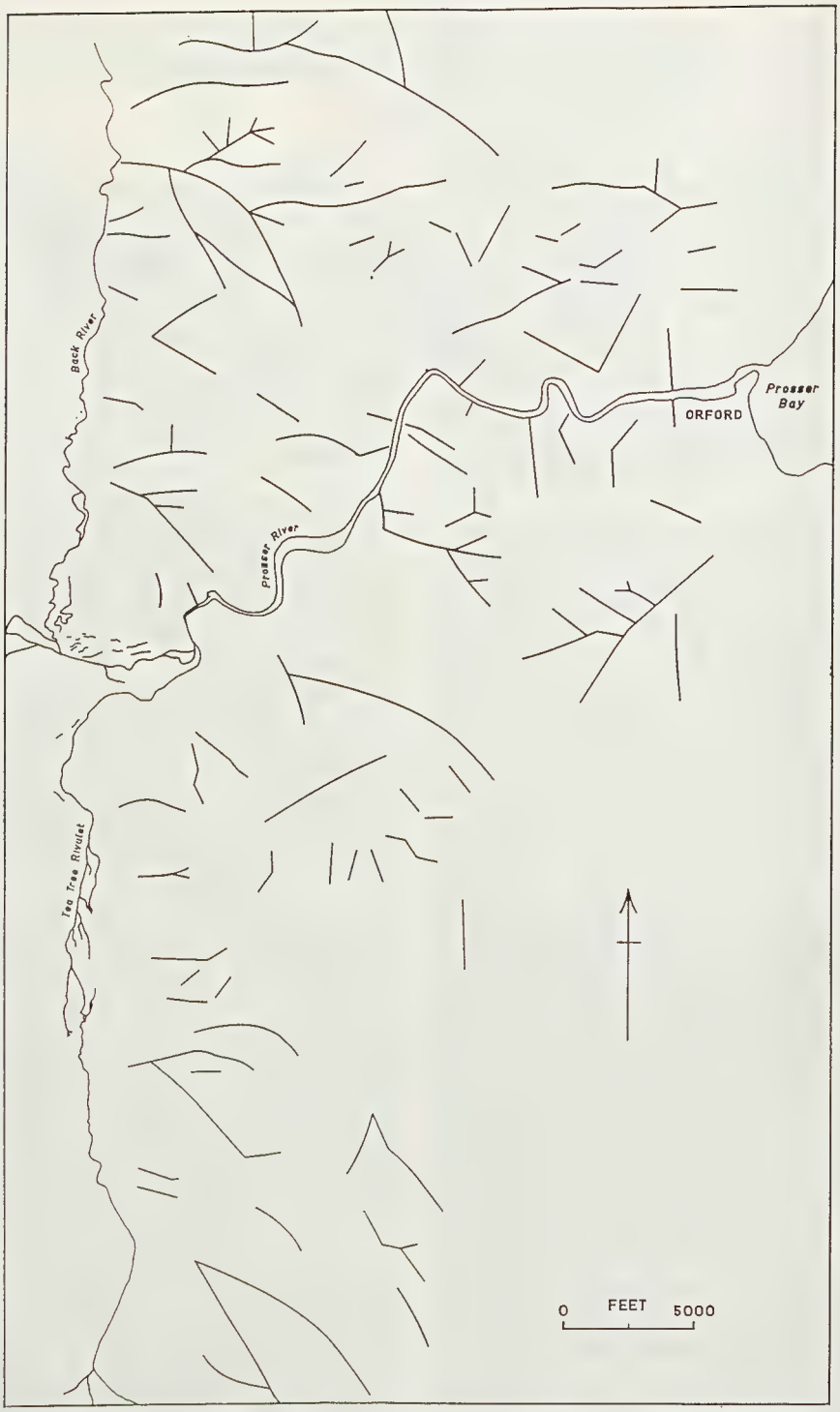

FIG 2.—Linears in the dissected area east of the Buckland Basin. The Eastern Boundary Fault is located parallel to and a short distance east of the Back and Tea Tree Rivers and is associated with strongly curved and splayed fractures.

Small flows and necks of Tertiary basalt outcrop two miles south of Buckland near Sally Peak and also in the Runnymede Basin, near Nugent and in the vicinity of Orielton and Pawleena.

Quaternary sediments occur along the coast and along the rivers especially in the Buckland Basin. The fluvial sediments of the basin will be discussed later.

Structure

The area has been faulted in the Tertiary in two dominant directions—

(1) A north-south direction with faults bounding the horst that runs parallel to the east coast. The westernmost fault has given rise to a prominent scarp, 8 miles long, which forms the eastern boundary of the Buckland Basin and is called here the Eastern Boundary Fault.

(2) A northwest-southeast direction with faults to the west of the Eastern Boundary Fault and appearing to terminate against it. They are tensional faults forming a complex graben.

Since the northwest-southwest trending faults appear to terminate against the Eastern Boundary Fault they are unlikely to be older than the latter. If both directions of faulting are of the same age the pattern can best be explained by regarding the north-south running faults as sinistral shear faults associated with tension faulting at an angle of approximately 40° to 50°. From aerial photographs all lineations in the dissected area to the east of the Buckland Basin were plotted on a map (fig. 2) and it would appear that the Eastern Boundary Fault of the Buckland Basin is associated with a number of strongly curved and splayed fractures. This association suggests that the fault is not a tensional one. It is most unlikely that the curved fractures are cooling joints since in the dolerite these tend to either straight or only gently curved. If the fault is a shear fault, the curved fractures are best explained as small thrusts. A third possibility is that the northwest-southeast faults are younger than the Eastern Boundary Fault. Both directions of faulting predate the formation of the Nugent Surface, an erosion surface standing at a height of 1100 to 1200 feet above sea level.

The relationship of the faults to the Tertiary sediments is important but not clear. The Tertiary sediments exposed in the bed of the Tea Tree are no more than 2000 feet away from the Eastern Boundary Fault. Had they been deposited before

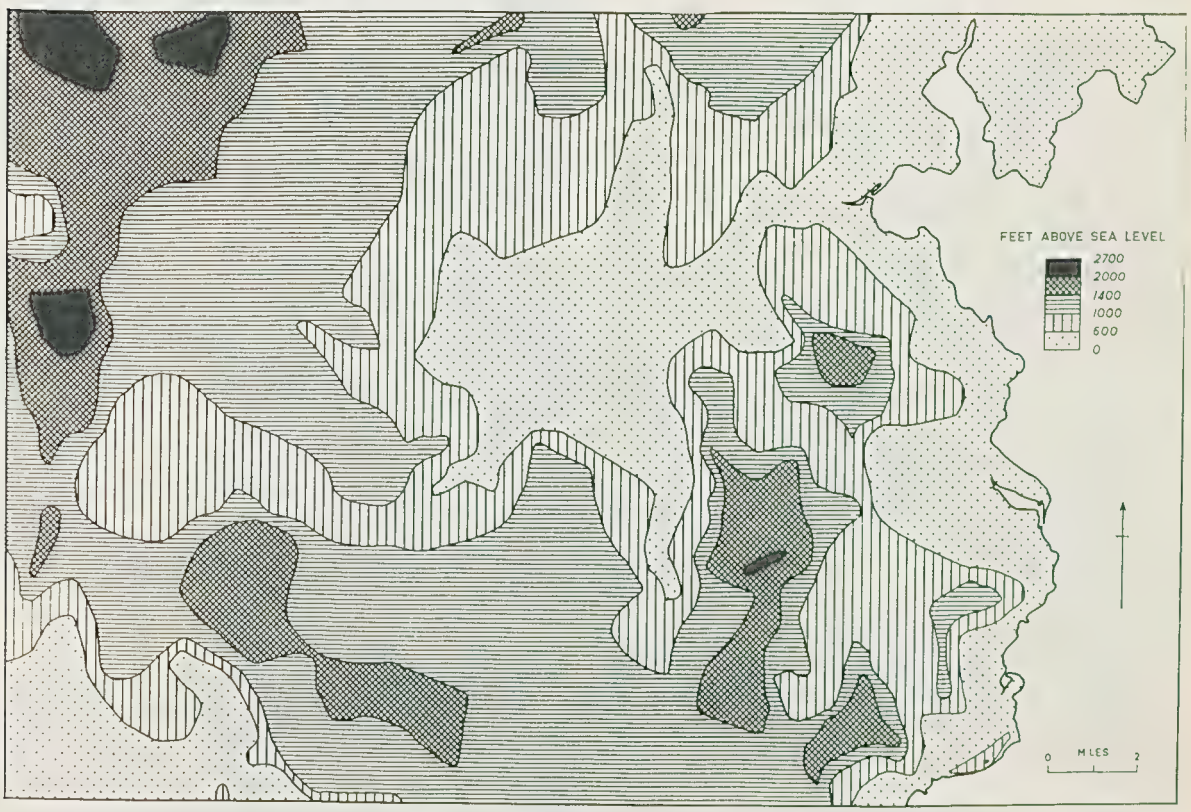

FIG. 3.—Generalized relief map of Buckland Sheet showing extent of the basin.

north-south faulting began one would have expected to find evidence that the beds were disturbed. Yet they are flat-lying and unjointed. It is therefore likely that they postdate the Eastern Boundary Fault. The relationship of the Tertiary sediments to the northwest-southeast trending faults is unknown. Whether or not the two directions of faulting are of the same age they provide a way in which the Buckland Basin could have formed as an enclosed tectonic basin. The Tertiary freshwater sediments which outcrop in the Tea Tree Valley could well represent the remnants of the infilling of such a basin. Their character suggests that they are lacustrine rather than fluvial sediments. If the Tertiary clays represent the infilling of the Buckland Basin during and after its formation, their early Tertiary age indicates approximately the date of at least one period of faulting. It is generally recognised that the early Tertiary was a period of major faulting in Tasmania. The character and extent of Tertiary faulting in eastern Tasmania is generally difficult to determine because of the prevalence of Jurassic dolerite and Triassic sandstones, neither of which provide suitable marker horizons.

EROSIONAL MORPHOLOGY

Relief

A generalized contour map (fig. 3), summit contour map and a summit frequency graph (fig. 4) were constructed from the Buckland topographic sheet. Since the generalized contours and summit contours give similar results only the generalized contour map is shown. Although summit concordance is lacking over much of the Buckland Sheet, it is marked over a considerable area to the west of Buckland and to a lesser extent around Nugent. This is reflected in the summit frequency graph showing a very marked peak at 1,100 to 1,200 feet. Much smaller peaks occur at 2,100 to 2,300 feet, 1,800 to 1,900 feet and 600 to 700 feet possibly indicating other erosion surfaces. The one at 1,100 to 1,200 feet is by far the most pronounced and is here called the Nugent Surface. It shows no evidence of having been faulted and since it is fairly widespread and in places very well preserved it is safe to say that no significant faulting has taken place since its formation. The surface is developed across both dolerite and Triassic sandstone but is best preserved on the more resistant dolerite, its extensive development on dolerite must have required a long period of time. However, the surface may at least in part be a structural one formed by the stripping of less resistant overlying sediments from the top of a dolerite sill. Since the area was affected by Tertiary faulting it seems likely that stripping was at best only a minor factor in its development. The surface is characterized by low, rounded hills and broad, flat-bottomed valleys which are frequently dry. As in the Buckland Basin, they may have been partly filled in by alluviation and the actual rock surface may not be as flat as it would appear.

Of the five surfaces postulated by Davies (1959) only his higher coastal surface seems to be present on the Buckland Sheet. Davies and the writer (fig. 4) have both produced summit frequency graphs showing a strong peak at 1,100 to 1,200 feet, which is slightly lower than the usual range of 1,200 to 1,500 feet given for the higher coastal surface. The lack of contoured maps for areas surrounding the Buckland Sheet makes it impossible to tell whether the 1,100 to 1,200 feet surface is continuous with similar surfaces at a slightly greater height in the Lower Midlands. To the west of Buckland it is separated from them by a continuous ridge extending from Black Charlie's Sugar-loaf to Mt. Hobbs and forming the watershed between the Prosser and Coal Rivers. The Nugent Surface could be a separate surface related to an earlier phase in the history of the Prosser and its tributaries.

Origin of the basin

In first analysis it would appear that the basin was erosional in origin, excavated in the easily weathered Triassic sandstones which occupy its floor, surrounded on three sides by more resistant dolerite. However, a completely erosional origin is now ruled out by the discovery of Tertiary clays in the Tea Tree Valley. The evidence suggests that the basin is basically tectonic in origin and that the faulting which led to its formation predates the development of the Nugent Surface. If the basin formed as an enclosed basin as postulated it must have been a lake of considerable extent at the close of the faulting. This lake was filled with sediment derived largely from dolerite terrain, probably during the early stages of the development of the Nugent Surface. At this time the Prosser may have flowed out between the Three Thumbs and Prosser's Sugar Loaf to enter the sea near Rheban (fig. 3) to be captured later by a smaller stream extending its drainage area inland from Prosser Bay.

A series of negative changes in baselevel then caused the Prosser to become incised in its new lower course while simultaneously causing it and its tributaries to cut rapidly into the unconsolidated lake sediments which had filled the Buckland Basin to an unknown height. The Tertiary clays are particularly susceptible to stream erosion and the probability of finding remnants of these beds at higher levels is remote. The clays outcropping in the bed of the Tea Tree Rivulet and also underlying the "Ironstone Surface", appear to be remnants of a more extensive lake sedimentation. The pronounced dolerite scarp forming the eastern boundary of the Buckland Basin is regarded as a resurrected fault scarp due to the removal of Tertiary sediments from the basin.

Drainage

The present drainage pattern is an asymmetrically centripetal one with six streams converging on the Buckland Basin and draining an area of approximately 270 square miles. The Back River and the Tea Tree Rivulet run parallel to the Eastern Boundary Scarp. The Prosser, Bluff and Sand Rivers flow into the basin from a northwesterly direction and the Brushy Plains Rivulet enters it from the south-west.

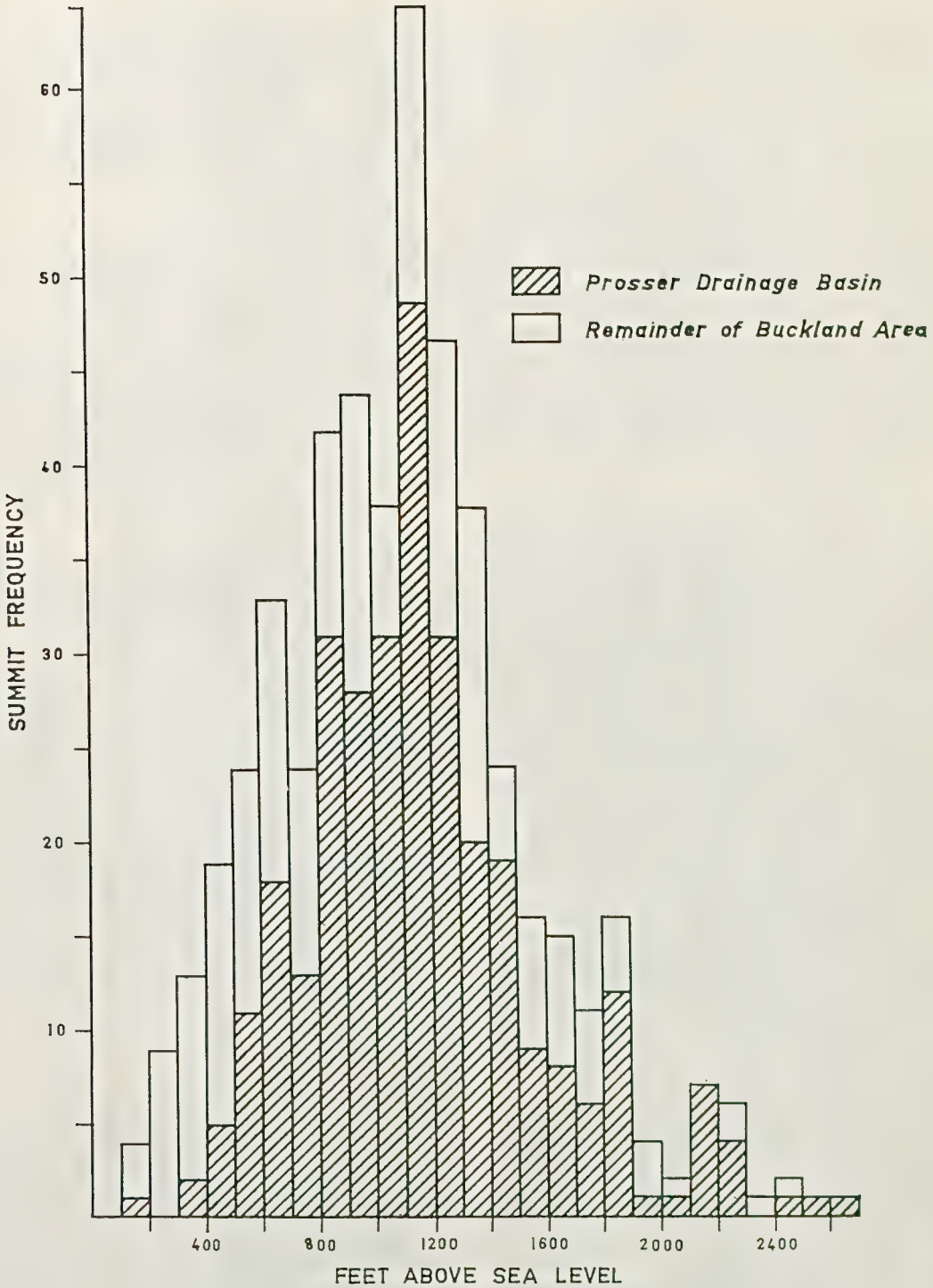

FIG. 4.—Summit frequency graph of Prosser drainage basin and Buckland Sheet.

There have been several river captures. The Sand River apparently once joined the Bluff River about five miles north of Buckland before being captured by a stream draining directly into the basin. The evidence for this is a distinct gap in the watershed between the Bluff and Sand Rivers, the floor of which is now approximately 200 feet above the present beds of the two streams. A classic example of river capture is found in the case of the Bluff. This river once flowed down a broad, dry valley—now followed by the Levendale Road—to join the Prosser just west of Buckland. It has since been captured by a small stream draining directly into the Buckland Basin thus creating a perfect elbow of capture. The river has now cut down about 50 feet below the windgap representing its old course. Immediately downstream the steep valley walls indicate strong incision after capture due to the sudden increase in erosive power at this point. Reversal of drainage has barely begun; there is a very short, shallow gully extending to the windgap which will eventually develop into a reversed stream. The upper part of the dry valley just below the windgap is rather swampy in nature.

The Prosser may once have flowed to the south of Buckland where it joined the Brushy Plains Rivulet before cutting its present course further north. The area through which the stream may have flowed is shown doubtfully as an old channel fill on the river terrace map (fig. 7) but no undoubted fluvial sediments have yet been found there. The area is fairly flat and stands at a height of 45 to 65 feet above the bed of the Prosser. Most of the soils appear to have been developed on colluvial material from the steep sandstone hills immediately to the south or on bedrock sandstone. Deep, strongly podsolized sands are found 300 yards south of the Tasman Highway bordering the road to Sally Peak. As these might be fluvial sediments four samples (S1-4) were collected for analysis. The method employed was that by Folk and Ward (1957). The mean size of the samples varied from .164 to .209 mm. (fine sand). They are moderately sorted, positively skewed and leptokurtic to very leptokurtic (excessively peaked). The percentage silt and clay present varied from 5.4 to 12.1%. The mean Wadell sphericity for 25 grains chosen at random from each sample ranged from .804 to .815. The sediment analyses permit but do not require a fluvial origin for the sand. Therefore it is distinctly possible but not proven that the Prosser once flowed south of Buckland.

Longitudinal profiles

It is probable that significant faulting has not taken place since the early Tertiary and certainly not after the development of the Nugent Surface. Hence irregularities (nickpoints) in the longitudinal profiles of the Prosser and its tributaries cannot be attributed to faulting. Such nickpoints are therefore due either to irregular changes in discharge, channel characteristics and load or to changes in baselevel, i.e. changes in the relative level of land and sea. One has to consider how the graded river in the sense of Mackin (1948) is affected by the lowering, rising or stability of baselevel. Mackin's definition of a graded stream is " one in which, over a period of years, slope is delicately adjusted to provide, with available discharge and the prevailing channel characteristics, just the velocity required for transportation of all the load supplied from above ". He also states that " slope usually decreases in a down valley direction, but because discharge, channel characteristics and load do not vary systematically along the stream, the graded profile is not a simple mathematical curve ".

(1) **Lowering of baselevel.**

When the baselevel is lowered the mouth of the stream is normally displaced both vertically and horizontally. There are three cases—

(*a*) If the slope of the newly emerged land is steeper than the gradient required for the river, the velocity of flow in this section will be accelerated resulting in down-cutting and the steepening (nickpoint) will be propagated upstream. The initial slope of the nickpoint will depend on the slope of the emerged land surface.

(*b*) If the slope of the newly emerged land is the same as the gradient required for the river the graded profile will not be affected.

(*c*) If the slope of the newly emerged land is less than that required for the river the velocity of flow in the lowest part of the river will be reduced and aggradation will occur. The flattening will be transmitted upvalley causing a wave of deposition.

Thus lowering the baselevel does not necessarily lead to rejuvenation. It does so only if the slope of the emerging land is steeper than the gradient required by the river to maintain its graded profile. The importance of the slope of the emerging land in this respect has already been pointed out by Sparks (1960). The Davisian idea that lowering of baselevel always gives rise to rejuvenation has also been criticized by Simons (1962) who in discussing Penck's work stated that: " Davis assumed a simple relationship between rates of upheaval and rates of river erosion. It is obvious if we accept the principle of nickpoint retreat that there is no simple relationship between changes in baselevel and river downcutting. A change of baselevel can only give rise to a nickpoint if it causes a discontinuity in the graded river profile.".

(2) **Rise of baselevel.**

Following Mackin many workers have suggested that a rise of baselevel causes aggradation. Mackin (1948) stated that " a rise of baselevel is equivalent to the rising of a barrier across the path of a graded stream. Each unit of increase in the height of the barrier tends to flatten the declivity immediately upstream. The stream unable because of the decreased declivity to carry all the load through the flattened segment, deposits in the segment, thus increasing the declivity and transferring the flattening upvalley. Continuation of the process results in upstream propagation of a wave or, better, of an infinite number of small waves of

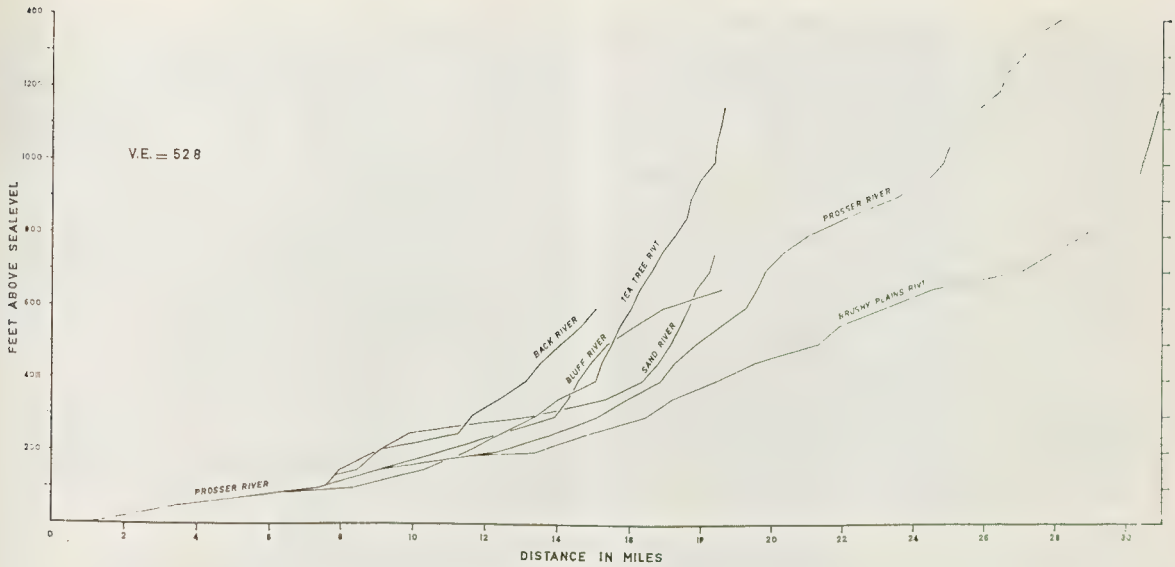

FIG. 5.—Longitudinal profiles of the Prosser and its tributaries.

deposition". Mackin supports his statement with examples of reservoir dams and debris barriers causing upstream aggradation in United States rivers. But from his own paper it is clear that it is not the dam itself which causes aggradation but the progressive regrading of the delta which begins to build out into the reservoir once it has been filled. It is not the rise in baselevel which causes aggradation but the building out of a delta when baselevel has ceased to rise. Applying this to streams in relation to sea level one can say that the rise in sea level since the last glaciation did not cause aggradation because it prevented river deltas from emerging. It is only since the postglacial rise in sea level was completed that river deltas began to build out. Contrary to Mackin the writer believes that a rising sea level does not cause aggradation but is the ideal condition for the rivers to maintain their graded profile.

(3) Stability of baselevel.

Under these conditions rivers are likely to build out deltas unless prevented from doing so by longshore or other ocean currents. The building out of a delta will cause aggradation upstream in a similar manner to that in reservoirs, but since the gradients of all larger rivers are usually low near their mouths the effects of such aggradation may be only slight.

The maintenance of a graded profile during a considerable period of time is required for the development of a rockcut surface, whether formed by pan- or pediplanation, especially where a stream flows over resistant bedrock. Hence a period of rising baselevel is more favourable to the development of rockcut surfaces than a stationary one. Such surfaces can however form with a stationary baselevel provided little or no aggradation takes place due to delta building at the mouth. When the development of rockcut surfaces is interrupted by a period of downcutting resulting from a lowering of baselevel and the consequent upstream migration of a nickpoint, the surfaces are transformed into rockcut terraces.

Profiles for the Prosser River and its tributaries were constructed from the Buckland Sheet contoured at 50 feet intervals. The inaccuracy of the contours, already discussed earlier, is a serious problem. The resulting longitudinal profiles (fig. 5) can only be discussed in the most general terms. The profiles of the rivers between contours are shown as straight line segments since a curved line would give a false sense of accuracy. The longitudinal profile of the Brushy Plains Rivulet approaches most closely the theoretical hydraulic curve being essentially concave upward. In the smaller rivers the profiles become more irregular. The Bluff and Sand Rivers and to a lesser extent the Prosser River show marked convexities. The most striking thing is that the longitudinal profile of the Brushy Plains Rivulet is well below that of the Prosser which is generally regarded as the main river. However, a comparison of the drainage areas shows that the Brushy Plains Rivulet drains an area of 70.35 square miles compared with 49.08 square miles for the Prosser above the confluence of the two streams. The designation rivulet is rather misleading since the Brushy Plains is easily the largest stream flowing into the Buckland Basin.

For further analysis of the basin a more accurate profile of the Prosser River was required. Since surveying the course of the river was impracticable, surveys were run down to the Prosser from bench marks and survey pegs along the Tasman Highway using a Dumpy level and staff. All heights were determined relative to the state datum which approximates to mean sea level. Heights at the Prosser Dam and up to a mile upstream were obtained from a contoured plan made

available by the Rivers and Water Supply Commission. Altogether the height of the Prosser was established at seventeen points over a distance of less than fourteen miles. The height of the Tea Tree Rivulet was determined at two points: one of them at Gatehouse's Marsh Bridge. The profile of the Tea Tree upstream from the bridge was also surveyed for 6000 feet using a staff and Abney level. The results are set out in fig. 6, where the heights given refer to low water stream level. Distances along the Prosser and Tea Tree were measured on aerial photographs. The profile of the Prosser is a smooth curve from the upper end of the Buckland Basin down to Brockley Bridge. There are three nickpoints in the profile: the first at Brockley Bridge, the second half a mile above the weir and the third about a mile upstream from the Prosser Dam. The nickpoint at Brockley Bridge appears to have no cyclic significance since the rock-cut Buckland Terrace maintains the same height above the river above and below this point. The Bluff, Sand and Back Rivers join the Prosser immediately upstream and the steepening of the gradient may be due to adjustment to the heavy load of sand carried by these rivers. The nickpoint half a mile above the weir is probably cyclic. Terraces below it cannot be correlated on the basis of height with those in the Buckland Basin (fig. 7). The third nickpoint about a mile upstream from the Prosser Dam is a very marked one. It occurs at a height of about 70 feet and from this point downstream there is a steep gradient to the tidal reach of the river except for a break of slope just above the Prosser Dam giving the nickpoint a stepped appearance. It is also interpreted as a cyclic nickpoint, since there appears to be no other reason for the sudden steepening of the profile. There is no evidence of recent faulting along the coast which could have initiated the lower two nickpoints and it is suggested that they are due to intermittent lowering of baselevel, which may have been epeirogenic or eustatic or a combination of both. The nickpoints may well be glacioeustatic—due to the lowering of sea level during Pleistocene glacials.

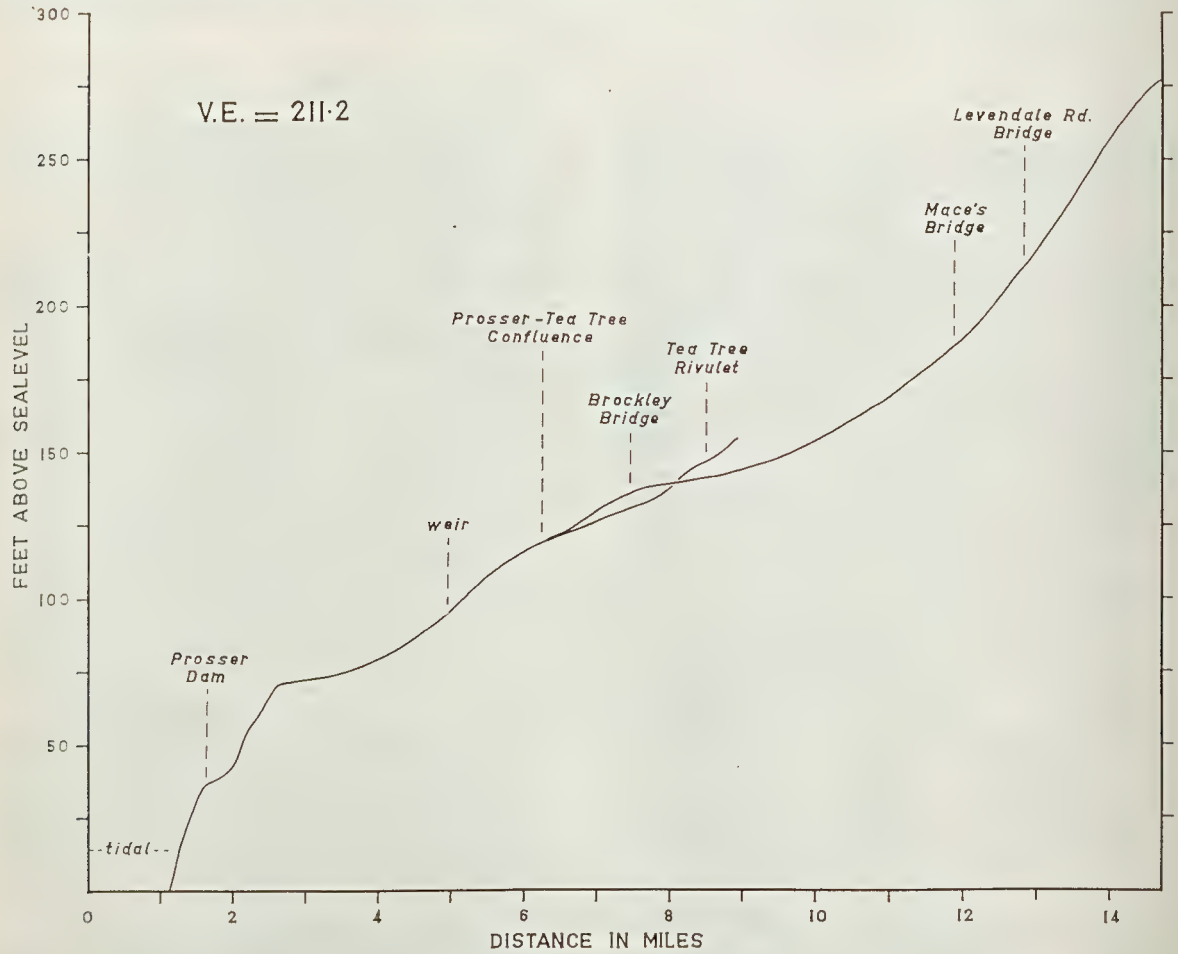

FIG. 6.—Longitudinal profile of the lower courses of the Prosser and the Tea Tree Rivulet.

An interesting feature of the profile of the Tea Tree Rivulet is that it passes below that of the Prosser just above the confluence although the former is a much smaller stream. The Tea Tree here flows through an area known as Gatehouse's Marsh and is actively aggrading its floodplain although vigorous downcutting occurs further upstream. Deposition in Gatehouse's Marsh may be due to a recent increase in load resulting from rapid gullying further upstream, aided by the damming back of the floodwaters of the Tea Tree by those of the Prosser. The floodplain of the Tea Tree is as much as 5 feet below that of the Prosser just above the confluence. The Gatehouse's Marsh situation may be analogous on a small scale with the Lowbidgee area on the Murrumbidgee River before it joins the Murray (Langford-Smith, 1960).

Erosional terraces

Two or possibly three erosional terrace levels can be recognised in the basin. They are: the Buckland Terrace at 30 to 40 feet, the Court Farm Terrace at 70 to 110 feet, and a possible higher level at 170 to 240 feet above river level (fig. 7). The height of the Buckland Terrace was established by transverse profiles surveyed by level and staff. Abney level and aneroid were also used. The heights of the Court Farm Terrace and a possible higher level have been established by aneroid only. All heights are given as heights above low water level of the nearest river. It was found that below the nickpoint half a mile upstream from the weir, terraces could not be correlated with those of the basin on the basis of height above river level. There is a rockcut terrace at 60 to 80 feet which may correspond to the Buckland Terrace and a lower terrace at 30 feet. Heights are indicated in fig. 7.

The Buckland Terrace is fairly extensive and remarkably flat. It is particularly well developed along the Prosser maintaining a constant height of 30 to 40 feet above the river throughout the length of the basin, and is cut in Triassic sandstones, Permian mudstones and Jurassic dolerite. On the dolerite it is much less extensive but particularly well preserved. No fluvial sediments have been found on the terrace. The soils appear to have been derived from the underlying rock. Podsols are well developed on sand- and mudstones and may have buckshot gravel in the profile but on dolerite they are thin and stony. Where the terrace is developed on Triassic sandstone it locally has on its surface shallow depressions due to wind deflation, two of which are quite large. One is found a short distance to the east of Buckland. It is approximately 900 feet long and up to 470 feet wide, elongated at right angles to the prevailing wind and backed by a low lunette. A sand sample taken from the windward side of the lunette (S8) was found to be moderately sorted with a mean size of .155 mm. The lunette is rather irregular in plan and has a vegetation of scattered eucalypts up to three feet in diameter with an undergrowth of cutting grass and bracken fern. The sand of which the lunette is composed has been leached. The depression has a mottled brown and dark grey clayey floor in contrast to the sandy soils surrounding it. On the western (windward) side it is rather irregular in outline, while the eastern side forms in part a smooth curve. It was formed by west-north-westerly winds which are still prevailing at the present time. The depression is located in line with the gap cut through the dolerite by the Prosser just north of Buckland. The other wind-blown depressions are found just west of the road to Brockley before it crosses the Prosser, the largest of these being 670 feet long by 370 feet wide. The eastern side is a curve concave to the wind, and there is no lunette. The other depressions are all much smaller and very shallow one showing a curve concave to the wind with arms trailing to windward making it crescent shaped in plan. None of them are backed by lunettes and all indicate prevailing westerly winds. It seems likely that the depressions were formed during a time more arid than the present as some have been ploughed without being activated. They may have formed by deflation of the sandy A-horizon of the soil during a more arid period or could even be the result of drier conditions combined with destruction of vegetation through burning off by the Tasmanian aborigines.

The Court Farm Terrace stands at 70 to 110 feet above river level. It is most extensive around Buckland and in general appears to have been stripped of any fluvial sediments it may have had.

North-west of Buckland is the dry valley through which the Bluff River used to flow before its capture and along its eastern side the terrace is found only 40 to 60 feet above the valley bottom. This is not unexpected since the Bluff River has cut down 50 feet since its capture while there has been little or no lowering of the bottom of the dry valley. Near the windgap through which the road to Levendale passes some deeply weathered gravels have been preserved on the terrace. Included in the Court Farm Terrace is the "Ironstone Surface" to the west of Court Farm, standing at an average height of 70 feet above river level but reaching 100 feet at Court Farm Hill. It is rather dissected and lumps of ironstone are scattered over its surface. The surface has been developed on Tertiary clays. Its soils were described by Loveday and Dimock (1958) as lateritic soils: "A typical profile has sandy surface and subsurface horizons with concretionary ferruginous gravel in the subsurface overlying a yellow-brown short clay, with red and grey mottling and ferruginous gravel. This continues to a considerable depth with a gradual lightening in colour to a light grey clay with occasional red and yellow mottling". Similar profiles were found by the writer in auger holes s, v and u (fig. 1). The following depths were reached before a hard layer was struck: 7 feet 5 inches in auger hole s, 6 feet 9 inches in v and 3 feet 7 inches in u. From the bottom of u chips of red ironstone were brought up suggesting that a layer of ironstone exists at a variable depth below the surface. Fragments of ironstone found on the surface may be up to a foot or more across but none of them show any sign of stream transport. The fragments are largest and most frequent on Court Farm Hill Individual specimens may show botryoidal, bedded or concentric structures. The material probably formed in situ as a ferruginous hardpan during a process of podsolization of an earlier formed soil. When the surface was degraded from its original

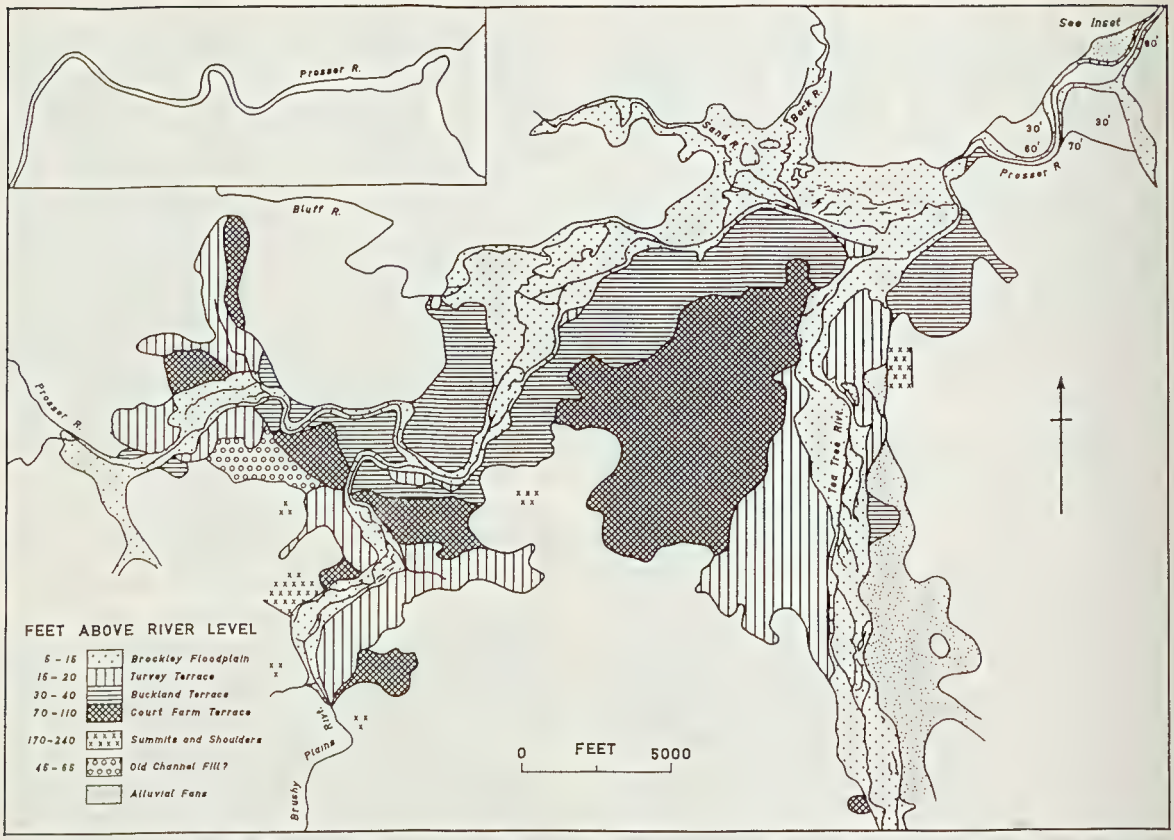

FIG. 7.—Distribution and extent of floodplain and river terraces in the Buckland Basin.

level by slope wash, the ferruginous hardpan was broken up and some of the larger fragments left behind. One specimen collected at Court Farm Hill had a distinct reddish colour and on X-ray diffraction analysis was found to contain hematite and quartz. Most of the ironstone however is limonite. The "Ironstone Surface" is at a slightly lower level than the Court Farm Terrace further west but has been included as part of the terrace because the ironstone provides clear evidence that the surface has been degraded.

There is some evidence of remnants of a higher terrace between 170 and 240 feet above river level. Summits and benches cut in both dolerite and sandstone are well developed along the Brushy Plains at an approximate height of 200 feet (fig. 7) and, along the Tea Tree east of Court Farm, a bench is cut in dolerite at a height of 200 to 240 feet. South of the Prosser one mile south-east of Buckland is a marked break of slope between 160 and 190 feet. They may all be remnants of a higher terrace but the evidence is not conclusive.

The erosional terraces are believed to have formed during long periods of stream profile stability separated by times of rapid downcutting resulting from the upstream migration of nickpoints. The origin of nickpoints has already been discussed.

ALLUVIAL MORPHOLOGY

Floodplain morphology

In the Buckland Basin the Prosser and its tributaries are associated with a floodplain which in places is more than half a mile wide. It has been named the Brockley Floodplain and its extent is shown in fig. 7. During heavy floods such as the one which occurred in April, 1960, the floodplain is converted into a temporary lake. When the water is low the flow is confined to a single channel but during floods more than one channel is occupied as some of the rivers are braided. Braiding is well developed at the confluence of the Prosser and Bluff Rivers and on the floodplain of the Brushy Plains Rivulet.

The character of the load transported by the rivers depends on the lithology of their drainage basins and there is a marked contrast between rivers draining dolerite terrain and those draining sandstone areas. Rivers draining dolerite carry a load of boulders, sand and clay, e.g. Prosser River, Brushy Plains Rivulet and Tea Tree Rivulet, whereas those draining sandstone carry mainly sand, e.g. Bluff and Sand Rivers. The Back River carries a mixture of the two types of load. The nature of the load is very important in understanding the composition of the alluvial deposits

and the behaviour of streams under conditions of aggradation. Fragments of bog iron ore were found in the Tea Tree Rivulet. They occur in gravel bars and also in the floodplain gravels and may be up to several feet across. They differ in several ways from fragments found on the "Ironstone Surface" (page 11). In some fragments iron oxide coats the surface of branches or roots of trees which themselves have been replaced by fine-grained structureless silica. The limonite coating has been deposited as a large number of small beads projecting from the surface suggesting deposition around bacterial centres. Other fragments consist of iron oxide cemented sediment showing hollows once occupied by stems and leaves while some are made of chemically deposited iron oxide showing a cellular structure. Some iron oxide from the surface of one of the fossil branches or roots was crushed for X-ray diffraction analysis. Since the iron oxide gave no pattern it was probably limonite. The only mineral which gave a pattern was doubtfully identified as manganese oxalate. Manganese is a common constituent of bog iron ores. The source of the bog iron is unknown. It may have been derived from swamps occurring at a height of 1700 feet one mile north of Prosser's Sugar Loaf, drained in part by tributaries of the Tea Tree Rivulet. This area has not been visited.

Three types of channels in the floodplain can be distinguished. They are—

(1) **Meandering channels** not yet affected by downcutting and characterized by their small width and irregular meanders. Some of these channels still carry low water flow. Examples are the channels of the Tea Tree downstream from Gatehouse's Marsh Bridge and the Prosser near its confluence with the Bluff. Others have been abandoned in favour of channels of type (2). Channels no longer carrying any flow or where the flow is insignificant are often choked with vegetation. An example which has been abandoned since the photograph was taken, occurs in the upper Tea Tree Valley.

(2) **Channels formed by gullying.** They are a striking feature of the basin and are typically U shaped in cross section, being deeper than the meandering channels, with the alluvium standing up as vertical cliffs. Low water level may be anything from a few to 18 feet below the floodplain but averages 8 to 12 feet. There is usually little or no scrub vegetation along the banks. These channels are much wider than the meandering ones and are relatively straight. They are usually formed by headward erosion, a minor exception being a small gully formed by forward stoping on the floodplain of the Bluff River. The channels are widened by slumping of the banks as they are undermined by floods. Gullying starts in suitable localities along the stream and during floods headward extension may be rapid. The head of a gully may be bulbous in which case it is usually occupied by a shallow pool or it may be branching (plate 2). According to reliable local reports a gully in the floodplain of the Tea Tree (plate 2) was initiated 80 years ago. In 1946, when plate 2 was taken, it had reached a length of almost two thirds of a mile by headward extension. In the 1960 flood the Tea Tree broke through into this new straight course abandoning its older meandering one. Because the gullies are relatively straight they have steeper gradients than the older courses and also have, at least initially, efficient cross-sections. Gullying is often promoted by the fact that many of the older courses occupy the highest part of the floodplain. During floods the water spills over sideways across the floodplain and flows down the lowest point until it rejoins the river. It is here that gullying is usually initiated. Since the lowest point of the floodplain is often at a junction with a higher terrace, gullying frequently occurs at or close to the edge of the floodplain (plates 1 and 2). There is a limit to the width of the channels. As the width becomes excessive longitudinal banks of sand and occasionally gravel are formed along the channel sides. These banks prevent further undercutting and the cliffs of alluvium start to degrade. The name "internal levees" is tentatively suggested as a suitable one for these features. Three samples of levee sand from the Prosser (S 5, 9 and 12) and one from the Bluff (S 13) have been analyzed (fig. 1). One sample of sand (S 11) from the tidal reach of the Prosser was also analyzed. The sands are well to moderately sorted with nearly symmetrical skewness. The exception is S 11 which is poorly sorted and negatively skewed. The different character of this sample is due to tidal influence.

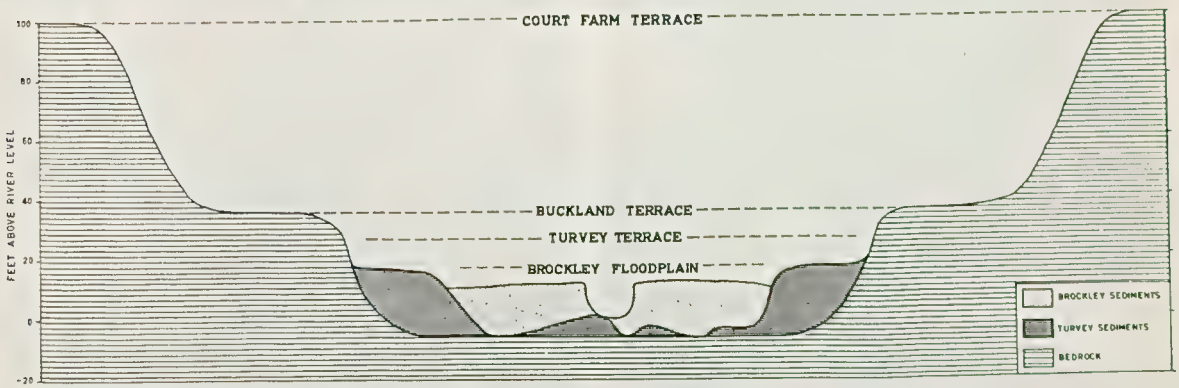

FIG. 8.—Generalized valley cross-section of Prosser River showing relationship of terraces and alluvial deposits.

(3) **Intermediate channels.** They are meandering channels which have been rejuvenated instead of abandoned as in the case of type (1) but, except for their meandering habit, they resemble the second class.

The last two types of channels are very reminiscent of the recently cut arroyos of the Colorado Plateau and adjacent parts of the dry Southwest of the United States (Bryan, 1925, Leighly, 1936). The bottom of none of the channels reaches down to the base of the floodplain (Brockley) sediments except in a few places. The Tea Tree has cut down to Tertiary clays near the boundary fence between Court Farm and Turvey's property, while Triassic sandstone outcrops in the bed of the Prosser River in at least three places.

Gravel bars are common in the beds of the streams except in the Bluff and Sand Rivers. They may form more or less straight across the bed or project into the stream from one bank at an angle such that the toe of the bar points downstream without reaching the opposite bank. In the latter case they are said to be skewed. Leopold and Wolman (1960) suggested that the occurrence of bars in a straight river should correspond morphologically to the point of inflection of a meandering channel and that the distance between successive bars was comparable to the wave length of meanders. They also stated that in some straight reaches gravel bars assumed the form of lobate wedges sloping alternately towards one bank and then the other. In the Buckland Basin bars in the beds of the streams show no regularity in either their spacing or the way in which they are skewed. In skewed bars the coarsest gravel is found in the middle of the stream becoming finer and the bar higher towards the bank from which it projects. The bars are usually separated by deep pools. In the upstream part of the Prosser before it enters the basin the pools often dry up in summer leaving an algal matte covering the boulders. This matte may prevent erosion during floods. The Tea Tree has cut through its floodplain deposits in places and has excavated deep pools in the Tertiary clays underneath while elsewhere the rivulet is cutting through floodplain clays. Here the stream has, during a period of low flows, excavated a one foot wide meandering channel in its bed with an interesting development of miniature meanders. At one place on the bank of the Sand River sand has been blown from the bed and has accumulated as a low dune with a steep lee slope slowly encroaching on the floodplain vegetation.

Overbank deposition on the floodplain is probably significant only in the Gatehouse's Marsh area discussed earlier. However, since 1963 was an extremely dry year the basin has not been seen under flood conditions, overbank flow occurring only once—in July. It was found that deposition on the floodplain of the Prosser was limited to small elongated mounds of sand deposited on the upstream side of gorse bushes which locally dot the floodplain. The greatest effect of the flood was to build up the "internal levees" described earlier. Afterwards the surface of the levees showed current ripples in places. The morphology of the floodplain suggests that at present scour rather than deposition takes place. The floodplains are marked by numerous lakelets always elongated in the direction of flow. They are particularly numerous and well developed on the floodplains of the Brushy Plains Rivulet and the Prosser below Brockley Bridge. Unlike oxbow lakes, they are usually straight or only slightly curved. Most of them are irregular in plan but on the floodplain of the Brushy Plains they are frequently wider at the downstream end tending to be tear-shaped. A few of the lakelets follow old stream courses and are rather sinuous. The lakelets are thought to be due to floodplain scour. Where gullies are formed by headward extension some may be incorporated in the advancing gully. Scour lakelets also occur in Gatehouse's Marsh (Plate 1) where at present deposition is dominant. Their outlines are less distinct and vegetational zoning is characteristic indicating that they are being filled in. Floodplain scour must have occurred in the not too distant past and it is possible that the recent change to deposition has taken place because of an increase in load due to rapid gullying further upstream.

Crevassing is shown by the Brushy Plains Rivulet just after its emergence from the hills. Here the fairly wide stream breaks up into a number of crevasses fanning out across the floodplain where large quantities of gravel are dumped. The place of the wide stream is taken by a much narrower stream the channel of which is discontinuous with the crevassed distal end of the larger stream. Crevassing appears to be the way in which the Brushy Plains disposes of a sudden excess of load. The reason is probably a rapid change in gradient combined with a sudden widening of the valley floor.

Where the floodplain (Brockley) sediments are exposed they have a characteristic section. Auger hole b in the floodplain of the Prosser (fig. 9) gave the following profile:

0—1'9" dark brown loam, somewhat clayey from 9" to 1'2".
1'9"—5'10" black clay rich in organic matter.
5'10"—8'1" sticky yellow-brown clay.
8'1"—10'7" mottled grey and brown sand.
10'7" + gravels.

The black clay, rich in organic matter, is very characteristic of the Brockley sediments wherever dolerite has been the source rock. The yellow-brown clay is not always present. In the Tea Tree Valley this horizon is usually a brown clayey sand. Numerous good exposures of Brockley sediments can be seen exposed by recent gullying. There is usually but not always a variable thickness of gravels at the base and near the head of the Tea Tree Valley bands and lenses of gravel occur higher up in the succession. In this locality logs up to several feet in diameter are present. A sample for C 14 dating was taken from a log approximately one foot in diameter and seven feet below the surface. It gave a date of 4435 ± 110 years B.P. indicating a mid-Recent age for the deposition of the Brockley sediments. A well made aboriginal scraper was found in situ approximately 8 feet below the surface in the Brockley gravels on the bank of the Tea Tree approximately 1000 feet upstream from the Court Farm-Turvey boundary (R 8 on fig. 1) indicating mid-Recent aboriginal occupation of the Buckland Basin.

A problem in the study of the floodplain sediments is to what extent differences in section are due to sedimentation or to soil development. The surface layer of dark brown loam shows sedimentary layering in some places at least, indicating that some of the characters of the top horizon are not pedogenic. The floodplains of the Bluff and Sand Rivers consist of a thick deposit of sand showing a little podsol development with thin A and B horizons marked by slight changes in colour. The floodplains of the Back River and the Prosser below its junction with the Bluff and Sand contain a mixture of sediments derived from both dolerite and sandstone terrain.

In the Tea Tree Valley a refraction seismograph was used to determine the thickness of alluvium (cf Dury, 1962) on the floodplain as well as the alluvial Turvey Terrace, overlying Tertiary freshwater sediments. The locality chosen had the advantage that the survey could be started from a known section exposed in the banks of the Tea Tree Rivulet. The following seismic velocities were determined:—

Turvey alluvium—1,125 feet/second.
Brockley alluvium—1,200 feet/second.
Tertiary sediments—4,400 feet/second.

The large difference in seismic velocities between the Tertiary sediments and the alluvium made it relatively easy to determine the boundary between them. The results obtained from the survey are shown in figure 10.

The floodplain vegetation of the Prosser, Tea Tree and Brushy Plains was originally dominated by dense tea tree scrub. The floodplains of the Bluff and Sand Rivers were better drained and supported a more varied and open vegetation including eucalypts. The floodplains were largely cleared during the first half of the 19th century and it is certain that most, if not all, of the gullying has occurred since then.

Where the lowest point of the floodplain is away from the river and borders a higher terrace, underground percolation may occur. In the case of the Prosser floodplain it is indicated by the depression of the water table in auger hole c (fig. 9).

The river meanders cannot be analyzed quantitatively because of their irregular nature. There is a marked contrast between the ingrown meanders cut in bedrock in the upper reaches of the streams and below the Buckland Basin, and the alluvial meanders within it. The ingrown, rock-cut meanders have a very much larger meander length and amplitude than the alluvial ones. Although the rivers in the basin are confined to one channel during times of low flow they tend to use more than one channel during floods. In addition much of the flow tends to be dispersed over the floodplain causing any floodplain channel at bankful discharge to carry very much less water than a corresponding channel in an ingrown meander. Also many ingrown meanders have been partially inherited from an earlier cycle and may not be adjusted to present discharge.

Other alluvial landforms

In addition to the floodplain there is evidence of another period of alluviation in the form of an alluvial terrace—the Turvey Terrace, which occurs at heights of 15 to 20 feet above river level. It has been identified along the Tea Tree, Brushy Plains and Prosser Rivers but is best preserved in the Tea Tree Valley. Near the Court Farm-Turvey boundary the rivulet is cutting into the edge of the terrace and a complete section is exposed. The Turvey sediments in the section have a maximum thickness of sixteen feet and are underlain by Tertiary clays (fig. 10). Like those of the floodplain the Turvey sediments are characterized by a variable thickness of coarse gravels at the base. These Turvey gravels are more consolidated than the Brockley gravels making it possible to distinguish them in the field. Remnants also occur in the bed of the Prosser upstream from Buckland where they are overlain by Brockley gravels. In the bed of the Tea Tree Rivulet the Turvey gravels form a resistant bar across the stream with a small waterfall. The basal Turvey gravels are overlain by a sequence of silty sands. A good section is exposed only along the Tea Tree. The terrace has well developed soils containing a variable amount of ferruginous gravel. Three auger holes e, w and y (figs. 1 and 9) were put down to get an idea of the soil profile and to collect samples for mechanical analysis. The following section was obtained in auger hole e.

0'—1'2" brown sand.
1'2"—2'7" yellow brown sand.
2'7"—2'11" light brown sand with numerous small pebbles.
2'11"—4'5" mottled brown sand with some ferruginous concretions.
4'5"—5'6" grey and brown mottled silt.
5'6"—15'2" grey and brown mottled sand.
15'2"—17'1" grey sand with sandstone fragments near base.
17'1" sandstone.

Similar sections were obtained in auger holes w and y. The former penetrated 11' 4" of silty sands and was stopped by gravel while the latter reached a depth of 7' 7" before striking rock.

From all three auger holes samples were taken at one foot intervals for mechanical analysis. The sample numbers are shown on the index and sample map (fig. 1).

Grain size parameters were calculated using the method outlined by Folk and Ward (1957) whose parameters have been modified from those of Inman (1952) to provide a more detailed coverage of bimodal and strongly skewed size curves making the method particularly useful for fluvial sediments. Folk and Ward established mathematical relationships between mean size, sorting, skewness and kurtosis and showed that the relationship between them could be depicted in a four-variate graph. Insufficient analyses were done to check the validity of the mathematical relationships established between parameters. Of the Turvey sediment samples taken only those from auger hole e have been analyzed. There are seventeen samples (S 37-53). The variation in depth of all parameters, as well as silt and clay content, is shown in fig. 11. It was found that the mean size of the sediments

varied from 3.08 to 1.77 Ø (.118 to .293 mm.). The standard deviation ranged from 1.035 to 2.345 Ø, indicating that the sediments are poorly to very poorly sorted. Skewness ranged widely from —.164 to .534Ø. One sample was negatively skewed and four were nearly symmetrical while the remaining twelve were positively to very positively skewed. Kurtosis ranged from 1.31 to 2.61 Ø, all samples being leptokurtic to very leptokurtic. The analyses show a direct linear relationship between mean size and skewness. Folk and Ward found that skewness and grainsize are closely related and that the relationship is sinusoidal. However, within the mean size range of the samples analyzed the relationship becomes approximately linear.

In interpreting the results one has to take into consideration the effects of post-depositional changes due to soil development. The increase in mean size from 3 to 6 feet in depth is due to the formation of iron oxide nodules in the soil profile. Their formation has also affected the standard deviation (sorting) and skewness. With the formation of the nodules sorting becomes poorer and the skewness tends to change from positive to negative. Soil processes must also have affected the distribution of the silt and clay content suggesting that the relatively high concentration between 4 and 11 feet is at least in part due to downward leaching of clays.

Where the Turvey Terrace has not been dissected its surface is undulating. In the Tea Tree Valley it is covered with circular to slightly elliptical depressions, a single depression has a trilobate plan in the photograph (plate 2). They are quite shallow, being never more than a few feet deep and tend to be swampy, though most of them have been artificially drained by trenches. The largest and best example has been deepened to serve as a waterhole for stock and is approximately 180 feet long and 110 feet wide. The smallest depression is no more than 30 feet across.

Their origin is not known with certainty. They are unlikely to be wind-deflated hollows as, quite unlike the wind-deflated depressions on the Buckland Terrace, they show no preferred orientation. They cannot be karst phenomena as the Turvey sediments in which they occur are underlain by Tertiary clays while their shape in plan rules out a fluvial origin. The most likely explanation is that they are thaw sinks formed under periglacial conditions. Similar features have been found in Alaska (Hopkins, 1949) and France (Pissart, 1958). Pissart described more than 4,500 enclosed depressions south of Paris and suggested that most of them had a periglacial origin. Because they lacked annular mounds he thought that they were not relicts of pingoes (Pissart, 1956), but thaw sinks of a different kind. The vast majority of his depressions are circular to oval in plan, quite shallow and comparable in size with those found in the Buckland Basin.

The depressions in the Tea Tree Valley are approximately 200 feet above sea level whereas Loveday and Dimmock (1958) estimate that the downward limit of solifluction deposits is about 1,500 feet. However, periglacial activity is not just a function of height. The Buckland Basin is an enclosed basin surrounded on all sides by higher country (fig. 3) and in winter severe frosts occur due to marked temperature inversions. During the Pleistocene ice ages, frost action in the basin could have been sufficiently severe for permafrost to occur. In a discussion of thermokarst features in Alaska, Péwé (1954) found that permafrost occurred on the floodplains and alluvial fans while absent or insignificant on surrounding hill slopes. This also suggests that temperature inversions are important in the location of permafrost.

In the Tea Tree Valley just south of the Tasman Highway the Turvey Terrace shows evidence of an old stream bed of much larger dimensions than the present rivulet (plate 1). This prior stream can be traced for approximately two thirds of a mile and is sufficiently well preserved to permit the measurement of the channel width as well as the wavelength and amplitude of the meanders. The measurements were made from plate 1 and are approximate since the scale of the photograph is not known with absolute accuracy. The meander wavelength (L) is 3,450 feet, the amplitude (A) 923 feet and the channel width (w) 187.5 feet. Leopold and Wolman (1960) established empirical relations between size parameters for meanders in alluvial valleys and found that meander length is usually 7 to 10 times channel width. In this case the ration L/w is 18.4:1, which is almost twice the usual ratio. Leopold and Maddock (1953) found that there is a statistical relationship between width and discharge which can be expressed as $w = aQ^b$ where w is water surface width, Q is discharge and a and b are numerical constants.

Dury (1960) used this relationship in his study of misfit streams to calculate ratios between present and former discharges and stated that "the generalised relationship $w \propto Q^b$ can be employed to calculate the ratio between the discharges required to shape the large channels and the discharges that are shaping the present channels. Let W be the width of the large channel, Q the corresponding bankfull (or near bankfull) discharge, w the present bed width, and q the present bankfull (or near bankfull) discharge. Then

$$W/w = aQ^b/aq^b = (Q/q)^b$$
$$Q/q = W/w^{1/b}".$$

The formula can be used to compare the bankfull discharge of the prior Tea Tree with that of the present stream provided we know the width of both channels. Dury stated further that the "results obtained in this way are affected by the degree of accuracy with which the width of the large channels can be measured, and by the value taken for the exponent b". He suggests that "an average value of 0.5 for b seems well substantiated by much hydrological research".

The width of the prior Tea Tree was measured from plate 1 at two places where the channel was clearly defined. It was found that the channel width was approximately 187 feet. The width of the present Tea Tree cannot be measured satisfactorily upstream from Gatehouse's Marsh Bridge because the river here is actively downcutting into its floodplain. As a result the width is extremely variable. Gatehouse's Marsh downstream from the bridge is more satisfactory because here the stream

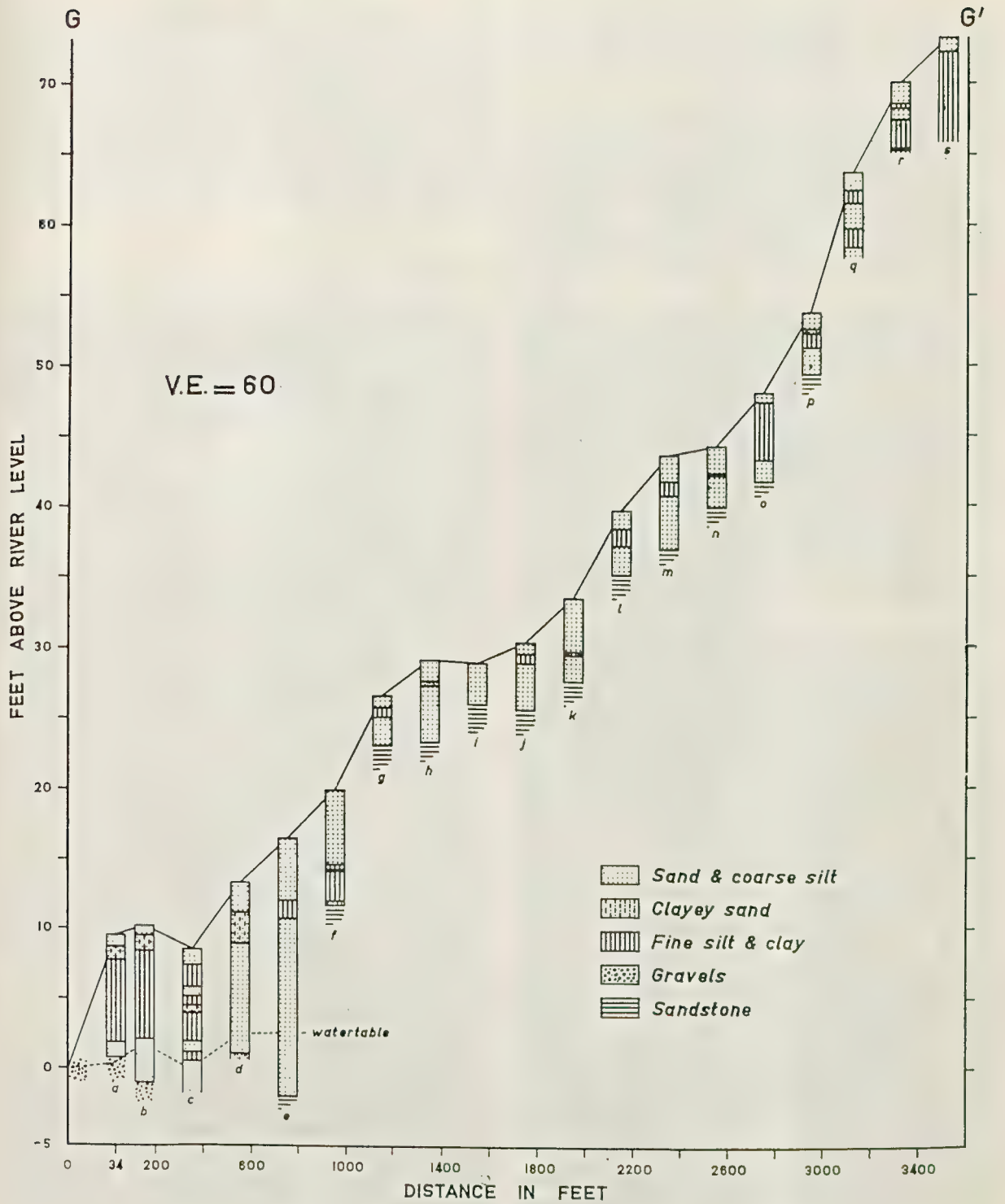

FIG. 9.—Series of auger holes at 200 foot intervals from the Ironstone Surface down to the Prosser River.

is not downcutting. The channel width was measured in several places and it was found that the maximum width did not exceed 25 feet. Taking the values W = 187 feet, w = 25 feet and b = 0.5 and substituting these in Dury's formula we get:

$$Q/q = (187/25)^2 = 56.$$

This would indicate that the bankfull discharge of the prior Tea Tree was fifty-six times greater than that of the present stream. The figure fifty-six should be regarded as very approximate but it does show that the prior Tea Tree was a very much larger stream. The reduction in discharge cannot be due to a reduction in the area drained by the Tea Tree as there is no evidence that its drainage area has recently been reduced by capture.

The problem is similar to that of the misfit streams investigated by Dury. The writer agrees with his views that " the disparity between present discharges and calculated former discharges is so great as to indicate a change in the regimen of runoff—a change that can scarcely not have been associated with a change in climate, including a change in the total annual precipitation ". It is difficult to imagine that the large changes in discharge are due to changes in precipitation alone and Dury has suggested three other possibilities—

(1) When the large channels were being cut, runoff was seasonally concentrated by snow melt.

(2) The yield of runoff per unit of precipitation was increased by reduced evapotranspiration.

(3) There has been a change in rainfall intensity.

Regarding (1) and (2) Dury stated that they " plainly refer to times of low temperatures ". Thus the very much larger discharge of the prior Tea Tree is best explained as a result of seasonally concentrated snow melt and reduced evapotranspiration. this may, or may not, have been accompanied by an increase in precipitation. The conditions suggested here would have existed in the Buckland Basin during the last ice age. The evidence from the prior Tea Tree is consistent with the suggestion of a periglacial origin for the depressions found further upstream on the Turvey Terrace.

Along the Eastern Boundary Scarp bordering the basin are a number of large low angle alluvial fans. They occur in the valleys of both the Back and Tea Tree Rivers but have been mapped only along the latter (fig. 7). Further south in the Tea Tree Valley they unite to form a continuous apron, with their apices from 60 to 150 feet above the level of the rivulet. Their surfaces are strewn with ferruginous (buckshot) gravel. Where the fans are dissected they are seen to be made up of layers of dolerite gravels sometimes separated by bands of clay. The matrix between the boulders is also rich in buckshot gravel. This gravel consists of magnetic iron oxide which is not derived from the dolerite but is concretionary in origin. It probably originates from the breaking up of older soils with ferruginous hardpans.

The last depositonal phase in the history of the fans was a very minor one and may have been due to a single flood. In some channels incised in the surfaces of the fans this phase is indicated by small fill terraces, while other channels were completely filled with gravels and have since partially re-excavated their courses exposing gravels of two distinctly different ages in their beds. The fans are truncated by the present floodplain and as well, one of them has been cut into by the prior Tea Tree. The evidence suggests that, apart from minor deposition confined almost entirely to the present channels, the fans predate the closing phase of the Turvey aggradation. They may be the same age as the Turvey Terrace but could well be older Pleistocene features with a complex history.

Discussion

There is evidence of two periods of alluviation in the basin. The older is represented by the Turvey alluvium and the younger by the sediments of the Brockley floodplain. The Brockley sediments are considered to be aggradational because the stream channels in general do not reach down to the base of the sediments. This is true even of channels which are actively cutting down. There is also a tendency towards braiding particularly in the case of the Prosser and Brushy Plains. The sediments are characterized by a typical sequence of horizontal layers. The floodplain was probably built up by deposition during floods accompanied by a certain amount of braiding. The Turvey Terrace is also thought to be aggradational. Although the alluvium is coarser and thicker it is also horizontal and shows the same sequence of coarse gravels at the base followed by finer grained sediments.

Aggradation may be due to tectonic, climatic or eustatic causes. Since there is no evidence of recent faulting or tilting, a tectonic origin can be excluded. Recent movements on the Eastern Boundary Fault can be ruled out by the fact that the rock-cut Buckland Terrace passes across it without change in height. Pleistocene lowerings of sea level, whether eustatic or epeirogenic, can be excluded as a cause of aggradation since the slope of the emerging land was sufficiently steep to produce nickpoints in the stream profile. Aggradation due to regrading of the river profile as a result of delta building can also be ruled out. Postglacial aggradation due to this cause is impossible since the drowned mouth of the Prosser has not yet filled up to above water level, while interglacial aggradation can be disregarded as both the Turvey and Brockley sediments postdate the last interglacial period (page 19). It is very likely that the two periods of aggradation are due to climatic causes.

A hypothesis of climatic terraces, which is often referred to as Huntington's Principle, was developed by Huntington (1914), who (quoted from Hadley, 1960) argued " that all terraces form in a similar manner as follows: The first cycle begins when the streams are deepening and widening their channels and are cutting into bedrock. Deposition is then brought about by a climatic change which encourages erosion. The process is reversed later and results in trenching of the alluvium. The vestiges of these alternating processes are terrace remnants ".

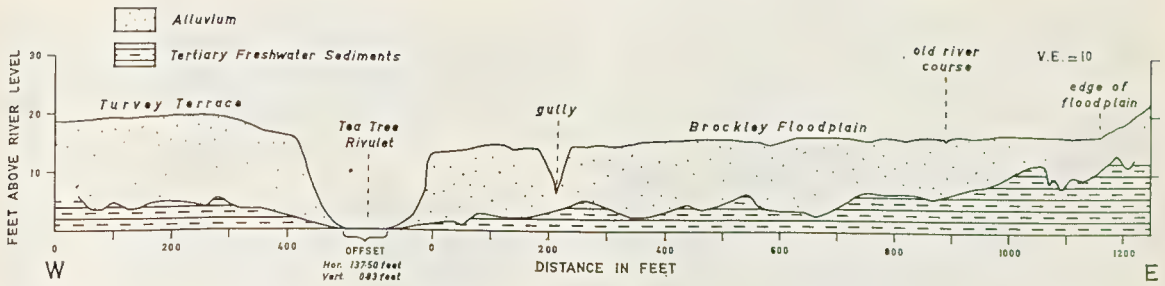

FIG. 10.—Seismic survey across the Tea Tree Valley showing depth of floodplain and Turvey alluvium.

Cotton (1945) restated Huntington's Principle and placed emphasis on the role of vegetation: "It may be urged with confidence that at least in certain cases an increase of precipitation will so encourage the growth of vegetation on catchment slopes in the headwater reaches of a river valley as to reduce their output of waste, and also that, even without such a reduction in the load to be carried by the river, higher precipitation will also increase the ratio of water to waste in the stream coming from the headwaters as to cause degradation down the valley; whereas a lessening of the ratio of water to waste in the stream, such as will be brought about by reduced precipitation probably aided by sufficient weakening of the vegetational protection of the soil in the catchment area to increase the absolute rate of supply of eroded debris, will cause overloading and result in aggradation of the valley". Basically Huntington's Principle means that any process which increases significantly the load/discharge ratio will tend to produce aggradation. In this respect the coarsest fraction of the load is most critical.

Three types of climatic conditions have been thought to give rise to the following classes of climatic terraces (Zeuner, 1959):

(1) fluvioglacial terraces.
(2) periglacial terraces.
(3) terraces in regions of arid and semi-arid climates.

Aggradation in arid regions is not only the result of a decrease in rainfall but also depends on rainfall distribution and intensity, temperature, vegetation and the rate of weathering.

In the Buckland Basin aggradation may have resulted from either a period of greater aridity or one of periglacial activity. A fluvioglacial origin can be ruled out since there is no evidence that any part of the drainage basin of the Prosser was ever glaciated. Carbon 14 dating has shown that the Brockley sediments are mid-Recent in age so that they cannot be of periglacial origin. The Brockley alluviation was probably initiated by a mid-Recent arid period (altithermal?). However, the vigorous downcutting which is now in progress in the basin is not directly a result of a wetter climate. It is almost certainly due to clearing of the dense tea tree vegetation from the floodplains. Perhaps the clearing upset a precarious equilibrium between aggradation and downcutting.

Evidence has already been presented that the Turvey Terrace was probably formed during a glacial period. It is not likely to be older than the last glacial (Wisconsin) judging by its state of preservation and by the fact that it was deposited at a level close to that of the present river profile. A periglacial origin for the terrace seems most likely, since solifluction deposits are known to occur in the drainage basin of the Prosser down to 1500 feet and periglacial activity must have greatly increased the load supplied to the streams. Zeuner (1959) considered that periglacial terraces occurred in cold, dry regions but it follows from Huntington's Principle that periglacial action could significantly change the load/discharge ratio by solifluction thus increasing the load without the need for a drier climate.

If the two aggradational phases have different origins as suggested, some differences in character between the Brockley and Turvey sediments can be expected. Such can be discerned although, where studied, both are derived from dolerite terrain. The Brockley alluvium is rich in clay. Black clays are very characteristic of the upper part of the sequence while yellow-brown clays are not everywhere present but also have a distinctive character. Although a thin band of medium grey clay was found in auger hole e, clays are rare in the Turvey sediments. However, under the binocular microscope they were found to be rich in unweathered plagioclase. This and the contrast in clay content suggest that the alluvium of the floodplain suffered more chemical weathering before deposition than that of the Turvey Terrace.

A comparative study was made of the basal gravels of the Turvey and Brockley alluvium. The method used to determine sphericity and form of the pebbles is the one developed by Sneed and Folk (1958). A total of 150 dolerite pebbles was measured, 75 from the Brockley gravels and 75 from the Turvey gravels. Care was taken to select sites with pebbles of comparable size. Both samples were collected from narrow bands one foot high and eight feet long. The Brockley pebbles were collected near R3-6 on the sample map (fig. 1) from the base of the gravels just above the contact with the Tertiary clays. The Turvey pebbles were collected near the locality marked R16-18 and taken two feet above the base of the gravels because of water levels.

The pebbles were scrubbed clean and the long (L), intermediate (I) and short (S) axes measured using vernier calipers. The measure of sphericity used was the maximum projection sphericity introduced by Sneed and Folk (1958) which has several advantages over the more widely used Wadell sphericity. Form was determined by calculating the ratios S/L and L-I/L-S, plotting the values on a triangular form diagram and using the form classification proposed by Sneed and Folk. Roundness was estimated by means of the visual comparison chart of Powers (1953). Small differences in sphericity, form and roundness were observed but they were not statistically significant.

In comparing the surface characters of the pebbles it was noticed that pitting due to chemical weathering appeared to be deeper and more frequent in the Brockley than in the Turvey pebbles. The pitting is due to the weathering out of pyroxene crystals in preference to plagioclase. In order to find out if the degree of pitting was significantly different in the two sets of pebbles a standard of comparison was made up. It consisted of four Brockley pebbles showing a range from smooth to severely pitted. All pebbles were compared with this standard and put in the class of the standard pebble which they most closely resembled. The following results were obtained:—

	Brockley Pebbles	Turvey Pebbles
Smooth	17	32
Lightly pitted	29	28
Moderately pitted	20	11
Strongly pitted	9	4
Total	75	75

A chi^2 test gave a value of 9.2 with three degrees of freedom so the difference is statistically significant. It suggests that the Brockley pebbles were subject to more chemical weathering before deposition than the Turvey pebbles. If weathering had occurred after deposition the Turvey gravels would have been more weathered since they are older.

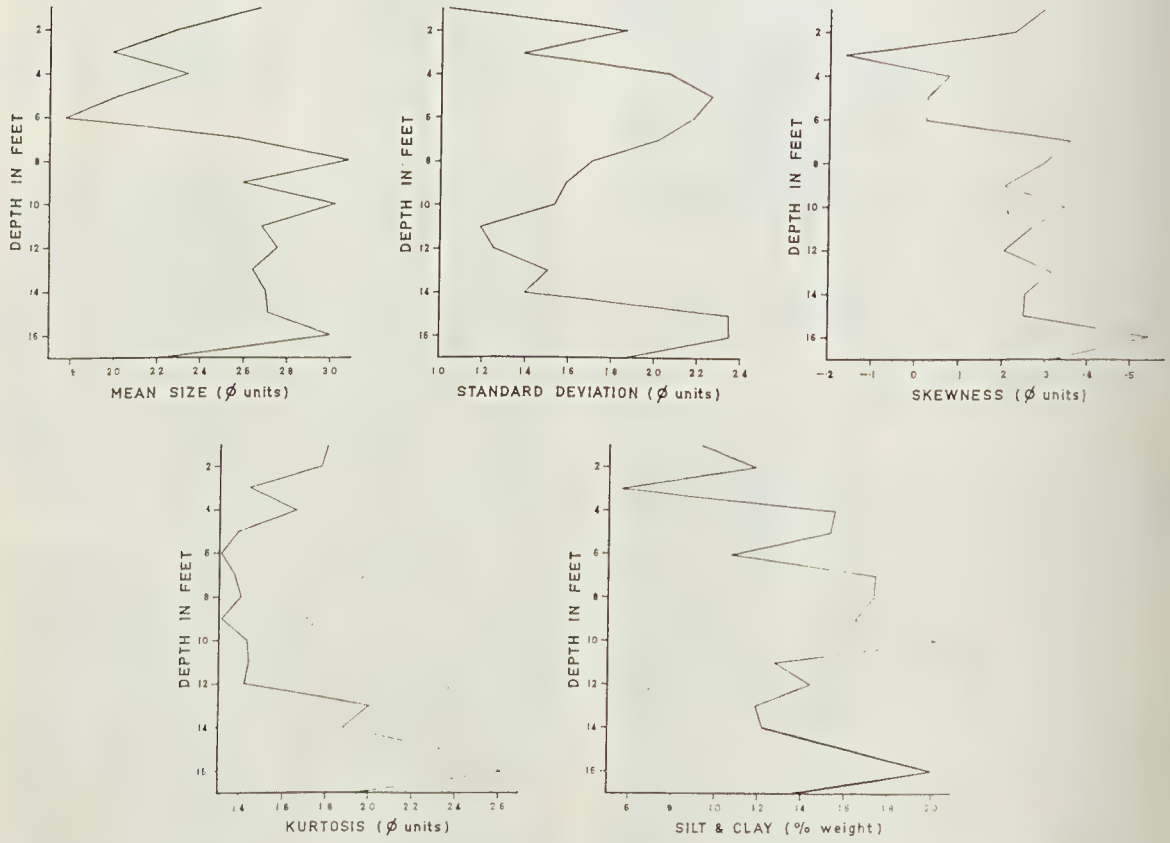

Fig. 11.—Sedimentary analyses of samples of Turvey alluvium taken at one foot intervals from auger hole e.

CONCLUSION

The Buckland Basin probably originated as an enclosed tectonic basin as a result of early Tertiary faulting. Two dominant directions of faulting are present but it is not known if both are of the same age. Early Tertiary freshwater sediments in the Tea Tree Valley are thought to represent remnants of the infilling of the basin.

Faulting predates the development of the Nugent Surface the formation of which required a long period of stability due to a stable or rising base-level. It may have been initiated during the Oligocene-Miocene marine transgression. The Prosser at this time may have flowed out between the Three Thumbs and Prosser's Sugar Loaf to enter the sea near Rheban, to be captured later by a small stream extending its drainage area inland from Prosser Bay.

As baselevel was lowered the Prosser became incised in its new lower course, at the same time cutting rapidly into the unconsolidated lake sediments which had filled the basin. The Eastern Boundary Fault was gradually exposed as a resurrected fault scarp. The summit level at 600 to 700 feet to the west and north of the basin marks another period of stability, perhaps in the Pliocene. This level predates a small basalt flow south of Buckland which goes down to less than 500 feet and may be Pliocene or early Pleistocene in age.

Oscillations in the relative levels of land and sea during the Pleistocene caused alternating periods of down-cutting and stability in the Prosser and its tributaries giving rise to erosional terraces. Three or four periods of stability are recognized in the basin. One doubtful period is suggested by the presence of summits and shoulders from 170 to 240 feet above river level while three others are indicated by the Court Farm and Buckland terraces and the erosional surface underlying the present floodplain. The first two periods were sufficiently long to enable the rivers to cut terraces in dolerite as well as in the softer rocks whereas the last one lasted long enough for a surface to be cut in the Tertiary clays and Triassic sandstones but not in the more resistant dolerite. This is well seen near Buckland where the Prosser and Brushy Plains have cut only a narrow channel into the Buckland Terrace. The development of the sub-floodplain surface has been retarded by periods of aggradation.

There is a considerable time lag between the formation of nickpoints and their effect on the Buckland Basin. The last two nickpoints formed have not yet affected the basin but must eventually do so even if no further lowering of base-level occurs.

The basin has been affected by two periods of alluviation represented by the Turvey and Brockley sediments respectively. The surface morphology of the Turvey Terrace suggests a periglacial origin. Chemical weathering of the Turvey dolerite pebbles is less than that of the younger Brockley pebbles. As well, the comparative absence of clay and the presence of unweathered feldspar in the Turvey sediments suggest deposition after a long period of predominantly mechanical weathering. Therefore a late Wisconsin age for them seems most likely.

Carbon 14 dating has shown that the Brockley sediments are mid-Recent in age. The high clay content and more pronounced chemical weathering of dolerite pebbles suggest a warmer climate for some time prior to and during their deposition. Aggradation is believed to have been initiated by a mid-Recent period more arid than the present which may also be responsible for the wind-deflated hollows on the Buckland Terrace. However, the present rapid dissection of the floodplain is primarily due to clearing of dense tea tree vegetation perhaps upsetting an already precarious equilibrium between aggradation and downcutting.

Alluvial fans along the eastern boundary of the basin may be related to an early phase of the Turvey aggradation or could be older Pleistocene features.

The almost complete removal of fluvial sediments from the older erosional terraces suggests a past period of much greater mass movement on gentle slopes. This applies particularly to the Buckland Terrace, only 30 to 40 feet above river level and remarkably flat. The older terraces may have been stripped of their fluvial sediments under the periglacial conditions existing at the time of the Turvey aggradation.

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Plate 1.—Aerial photograph of lower Tea Tree Valley. Prior Tea Tree is seen on Turvey Terrace at right hand side of photograph. Gatehouse's Marsh occupies top right hand corner. North is at the top of the page.

Photograph: Lands and Surveys Department. Scale: 1 inch to 750 feet.

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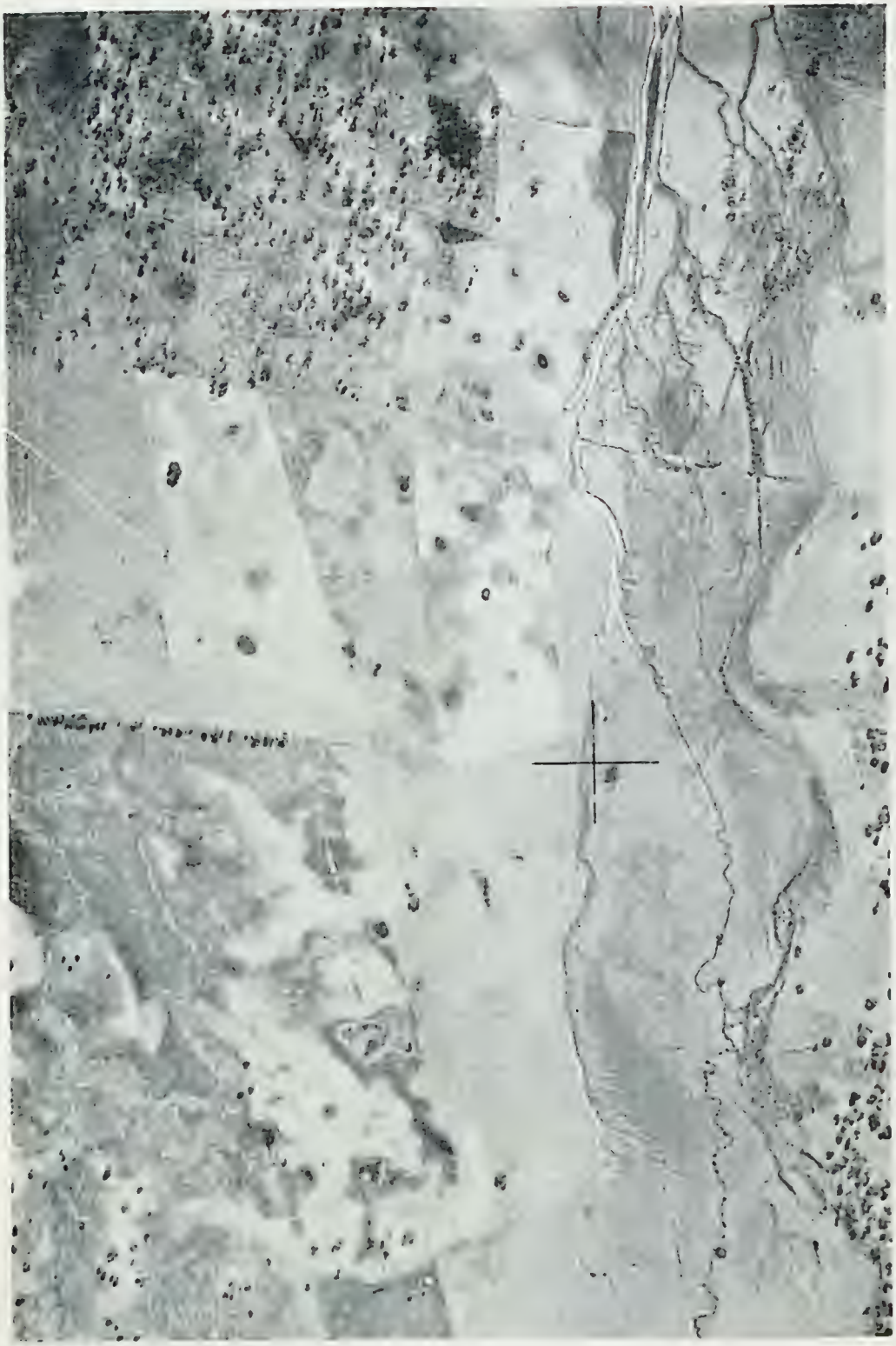

PLATE 2.—Aerial photograph of part of Tea Tree Valley showing extensive gullying of floodplain and branching nature of gully heads. Two thirds of photograph shows Turvey Terrace with circular and elliptical depressions which may be thaw sinks formed under periglacial conditions. North is at the top of the page. Scale: 1 inch to 750 feet.

Photograph: Lands and Surveys Department.

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